S/N° 482

BAND-PASS, BAND-REJECT
HIGH-PASS AND LOW-PASS

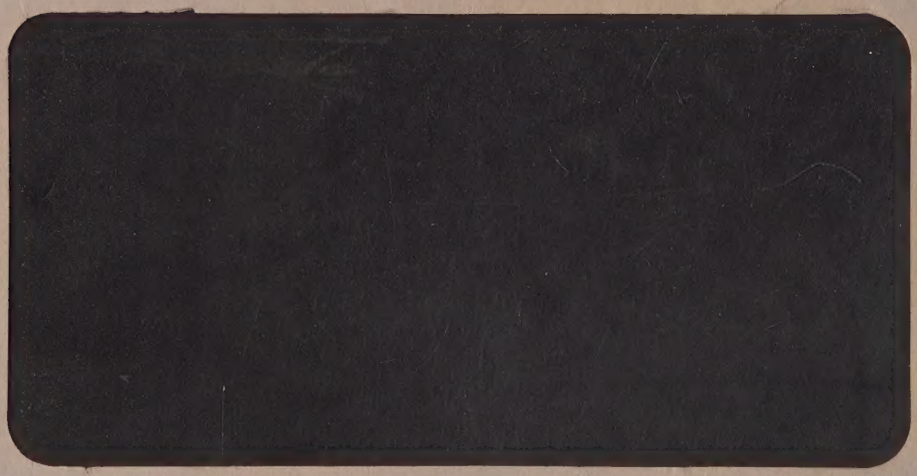
VARIABLE FILTER

MODEL 335(R)

OPERATING AND MAINTENANCE MANUAL

KROHN-HITE CORPORATION

580 Massachusetts Ave., Cambridge, Mass., 02139, U.S.A.



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Model 335

Model 335R

Figure 1. Model 335(R) Variable Electronic Filter

SECTION 1

GENERAL DESCRIPTION

1.1 INTRODUCTION

The Model 335(R) Filter, shown in Figure 1, is a Variable Electronic Filter covering the frequency range from 0.02 cps to 20 kc, and capable of operation in any of four functional modes: high-pass, low-pass, band-pass, or band-reject. The mode of operation is selected by means of a front panel FUNCTION switch. A fifth or BY-PASS position of the FUNCTION switch connects the input signal directly to the output terminals, without passing through the filter networks. This non-functional connection of the Filter is frequently useful in various test procedures where it is inconvenient to physically disconnect the input and output leads. The pass-band gain is unity (0 db) or 10 (20 db), as selected by a front panel GAIN switch, and the attenuation rate outside the pass band is 24 db per octave.

As shown in the Simplified Schematic Diagram, Figure 2, the Filter consists basically of an input amplifier, a variable high-pass section, a variable low-pass section, and an output amplifier. For operation in the band-pass mode, the high-pass and low-pass sections are connected in series. In the band-reject mode, they are connected in parallel. In high-pass or low-pass modes, the low-pass or high-pass sections, respectively, are disconnected.

The cutoff frequencies of both the high-pass and the low-pass sections are independently adjustable from 0.02 cps to 20 kc. Operation in the band-pass or band-reject modes permits passage or rejection of any band of frequencies between these limits. In the low-pass and band-reject modes, the Filter is direct coupled, passing all frequencies from DC to the selected cutoff frequency of the low-pass section. In the high-pass and band-reject modes, the upper 3 db point is at approximately 1 megacycle for 0 db gain, and approximately 200 kc for 20 db gain.

1.2 FILTER CHARACTERISTICS

The flexibility of bandwidth adjustment for each of the four modes of operation is illustrated in Figure 3. Band-pass operation for four different bandwidths is shown by curves A, B, C, and D (solid lines). Band-reject operation for a single rejection bandwidth with a cutoff frequency separation ratio of 10,000 is shown by curve E (dash lines). To avoid confusion, only this single example of band-reject operation is illustrated. As indicated by Figure 3, the mid-band gain varies slightly for different cutoff separation factors, although the attenuation rate (below the -12 db point) is approximately 24 db per octave for all curves.

Minimum pass band is obtained by setting the two cutoff frequencies equal. As shown in Figure 4, the resulting insertion loss is 6 db at that frequency,

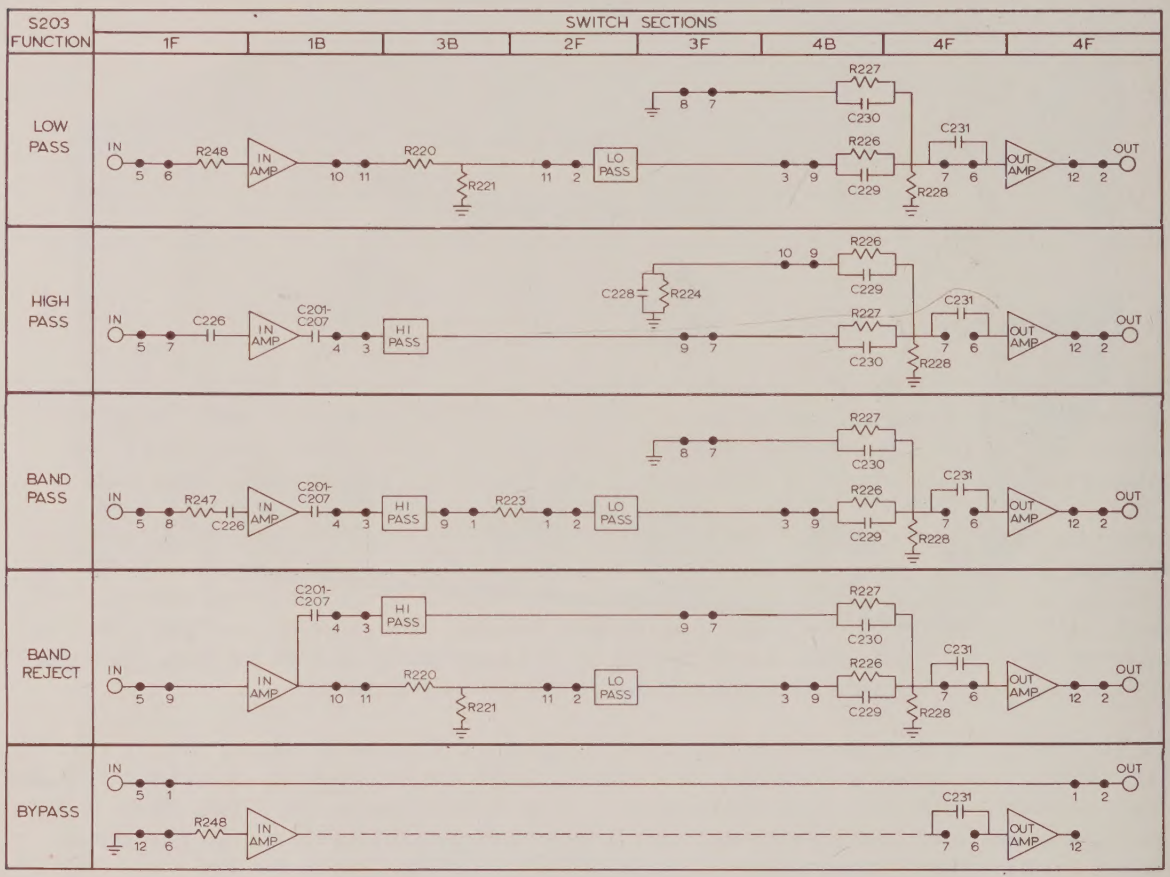

Figure 2. Simplified Schematic

and the 3 db points are at approximately 0.77 and 1.3 times that frequency. The dash lines illustrate 24 db/octave asymptotes intercepting the mid-band frequency at the zero-db point.

Minimum rejection band conditions are also illustrated in Figure 4. This response is essentially a sharp null with 3 db points at approximately 0.5 and 2.0 times the null center frequency, and is obtained by setting the high and low cutoff frequencies a factor of approximately 2 from the desired null frequency. The peaking factor of the Filter, selected primarily to minimize loss at the cutoff corners in band-pass operation, contributes greatly to the sharpness of the null. In contrast, a balanced parallel-T filter with no peaking circuit would locate the 3 db points at about 0.25 and 4 times the null frequency, and a flatter slope would result above the minus 25 db level.

Low-pass and high-pass operation are illustrated in Figure 5. The curve shown is for the low-pass mode; the high-pass curve is a mirror image about the unity abscissa. Note the effect of corner peaking shown in detail by means of the expanded GAIN scale.

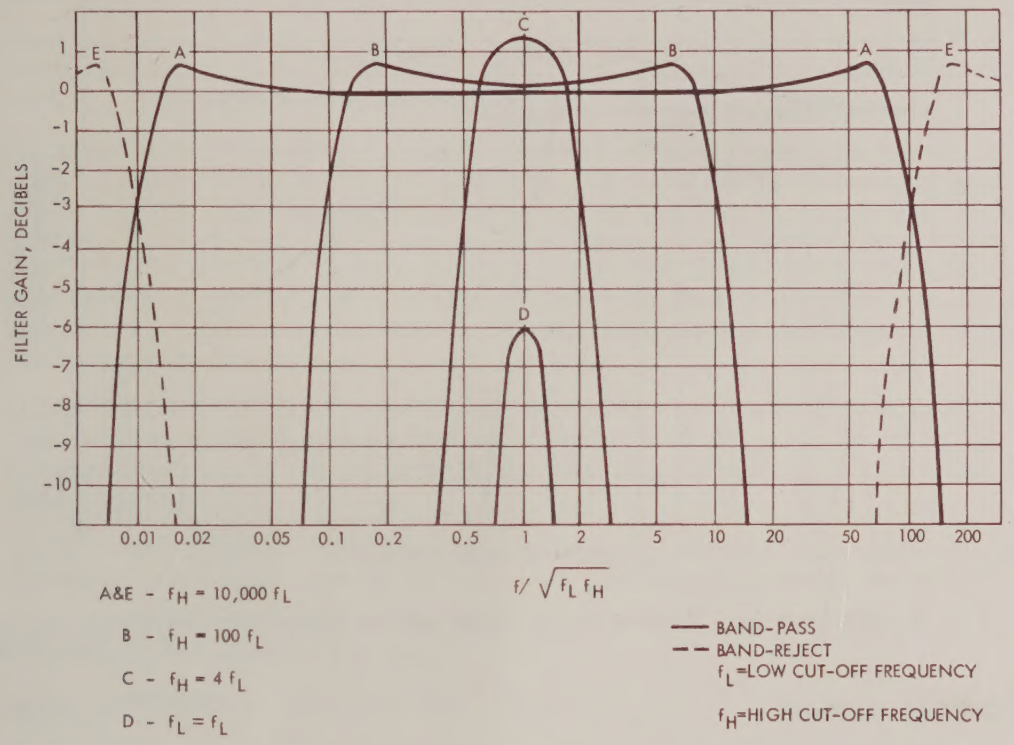

Figure 3. Normalized Filter Response

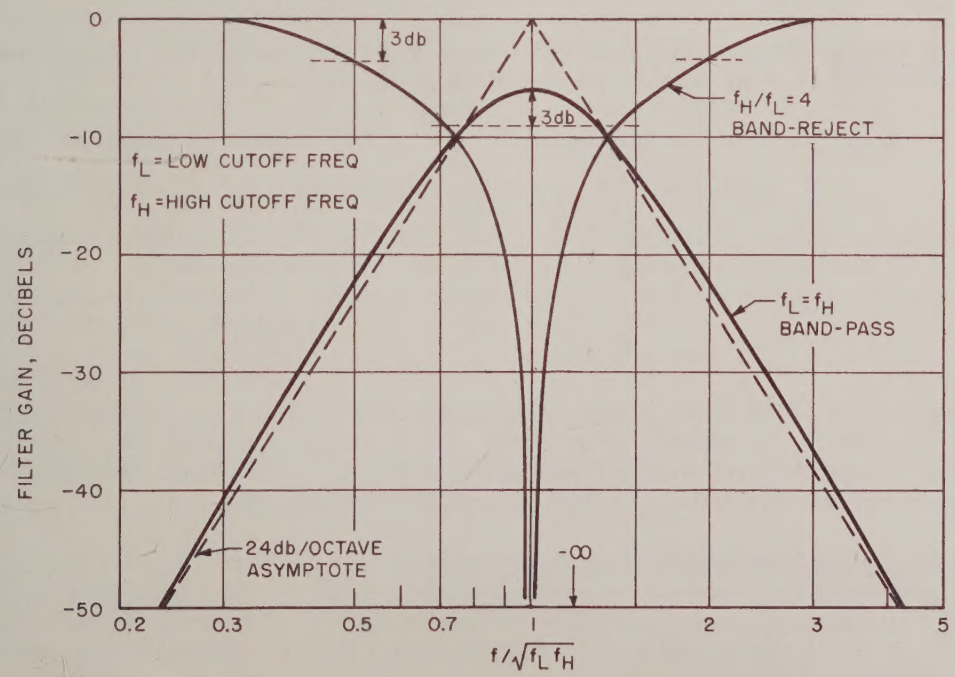

Figure 4. Narrow Band Operation

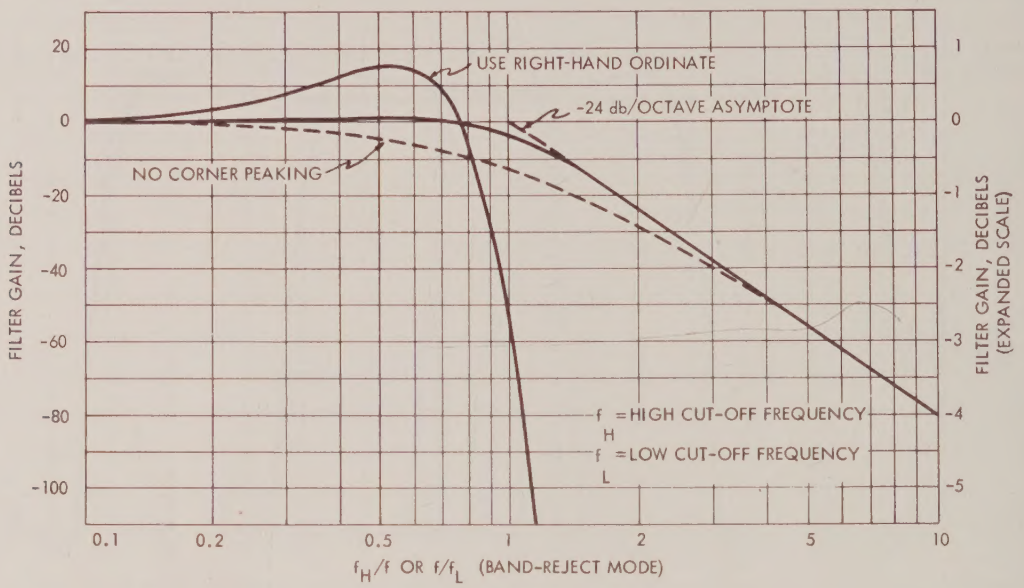

Figure 5. Normalized Attenuation Characteristics

1.3 TECHNICAL SUMMARY

Function: Low-pass, high-pass, band-pass, band-reject or by-pass. In the by-pass mode, the input signal is connected directly to the output terminals without passing through the filter networks. In all operating modes, the signal ground can be isolated from chassis ground if desired.

Frequency range: High-pass and low-pass cutoff frequencies adjustable independently from 0.02 cps to 20 kc, in six bands.

Band	Multiplier	Frequency (cps)
1	0.01	0.02 - 0.2
2	0.1	0.2 - 2.0
3	1.0	2.0 - 20
4	10	20 - 200
5	100	200 - 2,000
6	1,000	2,000 - 20,000

Frequency dials: Two illuminated dials, one for high-pass cutoff frequency, the other for low-pass cutoff frequency. Each is individually calibrated with a single logarithmic scale reading directly in cps from 1.9 to 21. Total scale length for all six bands is approximately 54 inches.

Cutoff frequency calibration accuracy: ±5%.

Bandwidth:

BAND-PASS MODE: Continuously variable within the cutoff frequency limits of 0.02 cps and 20 kc. For minimum bandwidth, the high-pass

and low-pass cutoff frequencies are set equal. This produces an insertion loss of 6 db, with the minus 3 db points at approximately 0.77 and 1.3 times the midband frequency.

BAND-REJECT MODE: Continuously variable within the cutoff frequency limits of 0.02 cps and 20 kc. The low-pass section response extends to DC. The upper 3 db point of the high-pass section is at approximately 1 megacycle for 0 db GAIN setting, and approximately 200 kc for 20 db GAIN setting. For minimum rejection bandwidth, the low-pass and high-pass cutoff frequencies are set a factor of approximately four apart. This produces a sharp null with theoretically infinite rejection of the center frequency.

HIGH-PASS MODE: Continuously variable, with cutoff frequency adjustable from 0.02 cps to 20 kc. The upper 3 db point is at approximately 1 megacycle for 0 db GAIN setting, and approximately 200 kc for 20 db GAIN setting.

LOW-PASS MODE: Continuously variable, with cutoff frequency adjustable from 0.02 cps to 20 kc. The pass band extends to DC.

Attenuation slope: Nominal 24 db per octave, with peaking factor to reduce attenuation at the cutoff frequency.

Maximum attenuation: Greater than 80 db.

Pass-band gain: Zero db ± 1 db with GAIN switch in 0 DB position, 20 db ± 1 db with GAIN switch in 20 DB position.

Input characteristics:

MAXIMUM INPUT AMPLITUDE: 10 volts rms with GAIN switch in 0 DB position, 1 volt rms with GAIN switch in 20 DB position. Above 50 kc the allowable input decreases at the rate of 6 db per octave, reaching approximately 0.5 volt at 1 megacycle with 0 db gain and 50 millivolts at 1 megacycle with 20 db gain.

IMPEDANCE: 20 megohms in parallel with 200 uuf.

MAXIMUM DC COMPONENT: 400 volts, in band-pass and high-pass modes. In low-pass and band-reject modes, the combined peak ac input voltage and dc input voltage should not exceed 15 volts for 0 db gain, or 1.5 volts for 20 db gain.

Output characteristics:

MAXIMUM VOLTAGE: 10 volts rms.

MAXIMUM CURRENT: 2 milliamperes rms.

INTERNAL IMPEDANCE: Less than 50 ohms.

DC LEVEL STABILITY (after warm-up): Less than 100 millivolts per hour (typically 20 to 30 mv) with GAIN switch in 0 DB position; higher with GAIN switch in 20 DB position. Temperature coefficient 10 millivolts per degree C with GAIN switch in 0 DB position.

Hum and noise: 80 db below maximum signal level.

Front panel controls:

High-pass CUTOFF FREQUENCY dial

High-pass cutoff frequency MULTIPLY DIAL BY switch

Low-pass CUTOFF FREQUENCY dial

Low-pass cutoff frequency MULTIPLY DIAL BY switch

FUNCTION switch

GAIN switch

POWER ON switch

Terminals: On both the front panel and the rear of the chassis, two multi-purpose binding posts for INPUT signal and return, two for OUTPUT signal and return, and a chassis GROUND terminal near the OUTPUT terminals.

Power requirements: 105-125 or 210-250 volts, single phase, 50-400 cycles, 100 watts. Hum and noise are increased by a factor of approximately 2 for 400 cycle operation.

1.4 DETAILED SPECIFICATIONS

While every effort has been made to provide a complete and definitive set of specifications for this Filter, there are some specifications which have not been included in the bulletin and Technical Summary for lack of space. These should be made familiar to personnel using the Filter in order to promote maximum understanding of the instrument and thus obtain best results from its use.

CUTOFF FREQUENCY CALIBRATION

The high and low cutoff frequencies, as defined below, should be within ±5% of the corresponding dial reading.

KROHN-HITE Electronic Filters are calibrated to conform to the following. From passive Filter terminology, the cutoff frequency is the frequency at which the gain of the Filter is 3 db down from the gain at the middle of the pass-band (band-pass mode), or 3 db down from the zero db reference (low-pass, band-reject, and high-pass modes). In the band-pass mode the gain varies with separation of the cutoff frequencies and is plotted in Figure 6 as a function of the ratio of high to low cutoff frequencies. Cutoff frequency gain approaches minus 3 db for wide separations (curve A of Figure 3), has a maximum of about minus 4.2 db for a separation factor of four (curve C of Figure 3), and goes to zero db when the cutoff frequencies coincide (curve D of Figure 3).

PASS-BAND GAIN

In the band-pass mode, the Filter output voltage under open circuit conditions will be within ± 1 db or within 20 db, ± 1 db, of the input voltage, depending

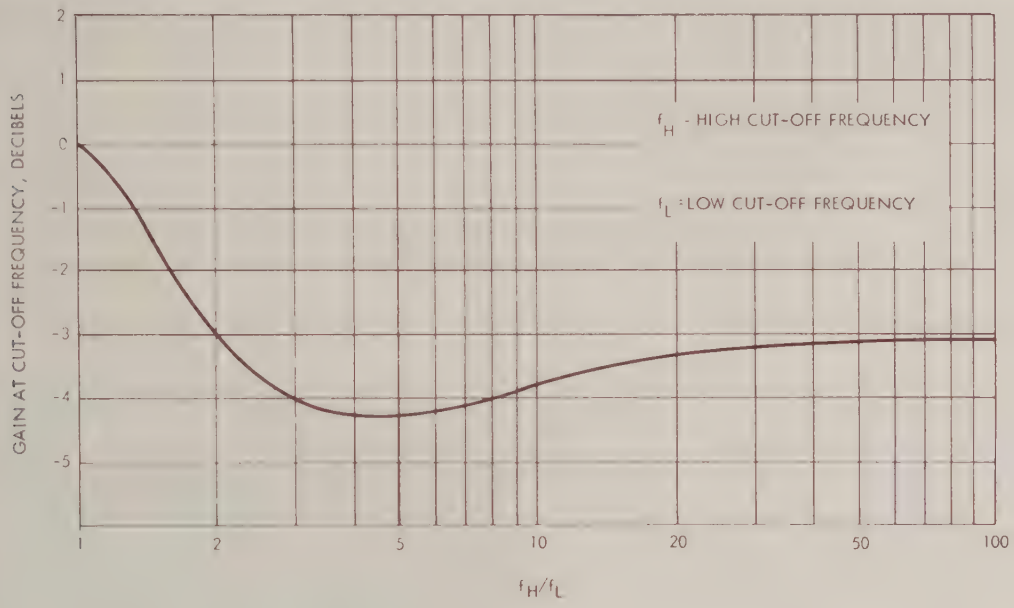

Figure 6. Cutoff Frequency Gain (Band-Pass Mode)

on the position of the GAIN switch, for all frequencies within the pass-band. The pass-band, for the purpose of specifying pass-band gain, is defined as the frequency spectrum from ten times the low cutoff frequency setting to one tenth of the high cutoff frequency setting. To determine the pass-band gain accurately, the high and low cutoff frequencies must be separated by a factor of at least one hundred, and the measuring frequency should be the geometric mean of these frequencies.

In the low-pass mode, the Filter output voltage under open circuit conditions will be within ± 1 db or within 20 db, ± 1 db, of the input voltage for all frequencies from DC to one-tenth of the low cutoff frequency setting.

In the high-pass mode, the Filter output voltage under open circuit conditions will be within ± 1 db or within 20 db, ± 1 db, of the input voltage for all frequencies from ten times the high cutoff frequency to 500 kc.

For the band-reject mode, the definitions of the low-pass and high-pass modes both apply.

ATTENUATION SLOPE

A typical attenuation curve is shown in Figure 5. At the cutoff frequency, the slope is approximately 12 db per octave, and at the 12 db point the slope has essentially reached its nominal value of 24 db per octave. The slope of the straight portion of the curve may be slightly less than 24 db per octave at certain frequencies because of cross-coupling effects.

INTERNAL IMPEDANCE

The rated internal impedance is the effective source impedance. In KROHN-HITE Electronic Filters, there is no requirement for the load impedance to

match the output impedance. Refer to Paragraph 1.3 for output signal voltage and current limitations.

INTERNALLY GENERATED HUM AND NOISE

The internally generated hum and noise measurement is based on the use of a Ballantine Model 310 Voltmeter, or equivalent. The measurement is made with the INPUT terminals connected by a shorting jumper, no other external signal connections to the instrument, and the voltmeter leads shielded.

MINIMUM BANDWIDTHS

With the FUNCTION switch on BAND PASS, the minimum pass-band is obtained by setting the high cutoff frequency equal to the low cutoff frequency.

With FUNCTION switch on BAND REJECT, the minimum reject band or null at any frequency is obtained by setting the high cutoff frequency (left-hand frequency dial and band multiplier switch) higher than the desired frequency by a factor of approximately 2, and setting the low cutoff frequency (right-hand frequency dial and multiplier switch) lower than the desired frequency by a factor of approximately 0.5. A sharper null may be obtained by successive readjustment of the two frequency dials, while monitoring the Filter output.

DISTORTION

Filter distortion is a function of several variables and is difficult to specify exactly. In general, if the Filter is operated within its ratings, distortion products introduced by the Filter and not present in the input signal will not exceed 0.5% of the output signal. In most cases, distortion will be considerably less than 0.5%.

TRANSIENT RESPONSE

The term transient response is sometimes used in reference to filters in an attempt to specify performance when impulse voltages are applied to the input. Mathematical analysis and laboratory measurements show that for a given input signal (complex wave, square wave, step function, etc.) all filters will produce an output signal that depends only on the transfer function versus frequency and is not affected in any manner by the electrical composition of the filter (RC, m-derived, etc.).

The phase and/or amplitude of the individual input signal frequency components may, however, suffer undue distortion at the output if the filter does not have a smooth transfer characteristic with no pronounced peaks. Distortion of this nature is minimized in the design of KROHN-HITE Filters. These Filters represent the optimum practical approach to ideal filter characteristics combined with versatility to give unsurpassed performance.

SECTION 2

OPERATING INSTRUCTIONS

2.1 INTRODUCTION

The Filter is adjusted and carefully tested before shipment to ensure that it meets all specifications. It is then aged and again tested to be sure that it is ready for use. The Filter is shipped complete, and after unpacking, is ready to be turned on and used.

Unpack the Filter carefully and inspect for damage that may have occurred during shipment. Check the cabinet for damage, and check for loose sub-assemblies and parts. Make sure electron tubes are properly seated. Check all front panel controls for freedom of operation.

2.2 LINE VOLTAGE AND FUSES

The Filter, as normally shipped, is connected for operation from an ac power source of 105 to 125 volts, 50 to 400 cycles, and uses a one ampere slow-blow fuse which is mounted on the rear of the chassis. It may be modified to operate from a 210 to 250 volt line by removing the two jumpers from the four terminal barrier strip, located directly underneath the power transformer, and adding a jumper between terminals 2 and 3 of the barrier strip. A 1/2 ampere slow-blow fuse should be used for 210-250 volt operation. Hum may increase as much as a factor of two when operated on a 400 cycle power line.

2.3 OPERATING PRECAUTIONS

Observe the following limitations on the Filter input signal:

MAXIMUM INPUT AMPLITUDE: 10 volts rms with GAIN switch in 0 DB position, 1 volt rms with GAIN switch in 20 DB position. Above 50 kc the allowable input signal decreases at the rate of 6 db per octave, reaching approximately 0.5 volt at 1 megacycle with 0 db gain and 50 millivolts at 1 megacycle with 20 db gain.

MAXIMUM DC COMPONENT: 400 volts, in band-pass and high-pass modes. In low-pass and band-reject modes, the combined peak ac input voltage and dc input voltage should not exceed 15 volts for 0 db gain or 1.5 volts for 20 db gain.

The following limitations apply to the Filter output signal:

MAXIMUM VOLTAGE: 10 volts rms.

MAXIMUM CURRENT: 2 milliamperes rms.

INTERNAL IMPEDANCE: Less than 50 ohms.

2.4 CONTROLS AND CONNECTIONS

Figure 7 shows the location of all front and rear chassis controls and connections. Filter functions are indicated in elementary form and a simplified output dc level adjustment procedure is given.

2.5 OPERATION

The recommended operating procedure is described below:

a. Make appropriate power connections as described in Paragraph 2.2.

b. Make appropriate connections to the INPUT and OUTPUT terminals of the filter.

NOTE

On both the front panel and the rear of the chassis, two multi-purpose binding posts are provided for the INPUT signal and return, also two for the OUTPUT signal and return, and a chassis GROUND terminal is provided near the OUTPUT terminals.

This instrument has the signal ground circuit isolated from the chassis. In most cases the signal ground will be connected to the chassis and a shorting link is provided between these two points at the rear OUTPUT terminals. If the Filter is to be used in a system where ground currents could be a problem, removal of the shorting link isolates the signal ground. Excessive noise voltage should never be allowed to develop between chassis and signal ground, however, because of the possibility of the noise being picked-up by capacity coupling to high impedance circuits and consequently added into the signal circuit.

c. Select correct GAIN setting for the signal level in use. Note that while the maximum input signal in the 20 DB position is one volt, and the maximum input in 0 DB is ten volts, the maximum output signal in both cases is ten volts. Observe the precautions of Paragraph 2.3 with regard to maximum input signal amplitude within the tuning range and also the maximum amplitude-versus-frequency limitation for frequencies above the tuning range.

d. Turn the FUNCTION switch to desired mode of operation.

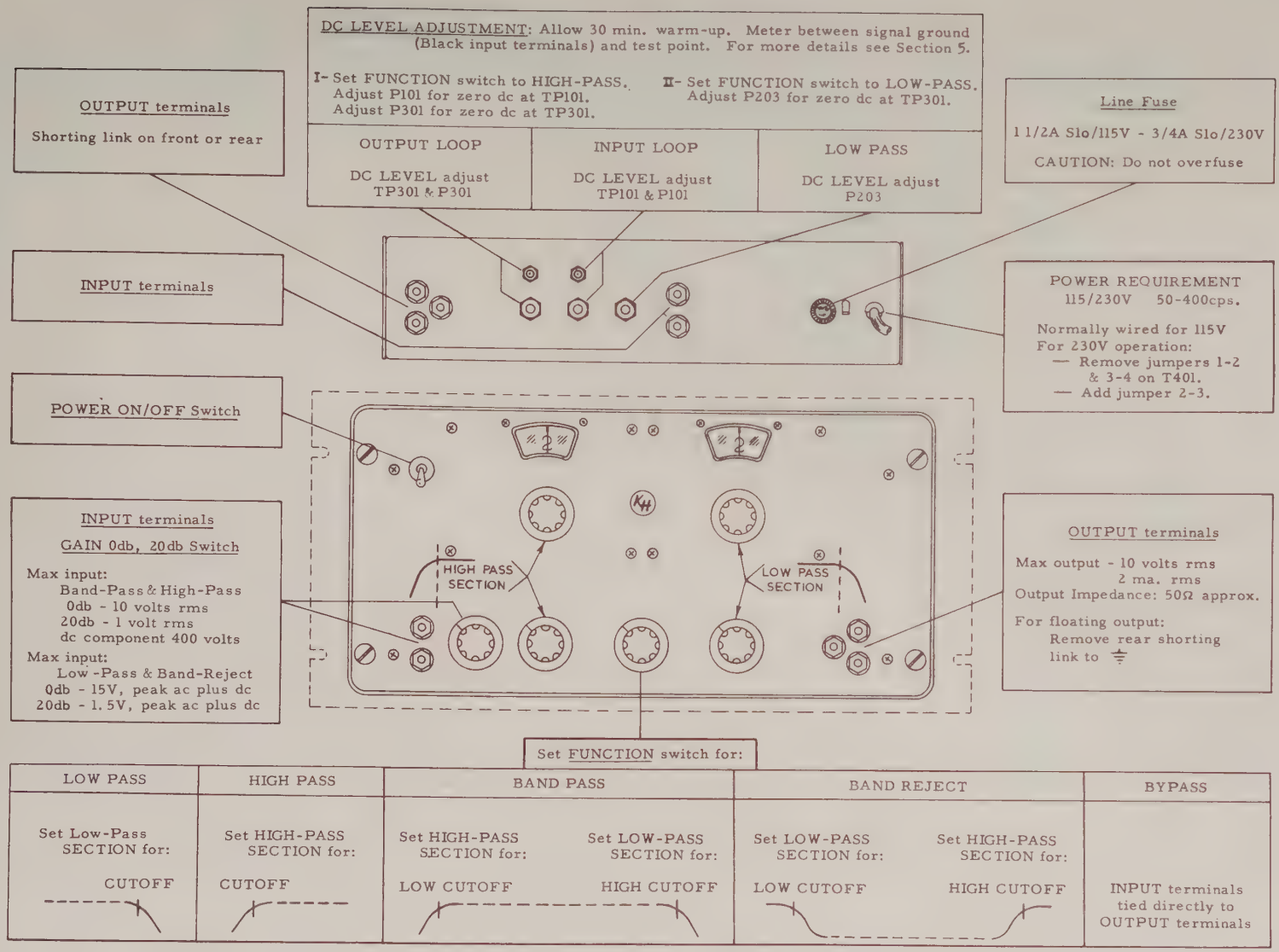
DC LEVEL ADJUSTMENT: Allow 30 min. warm-up. Meter between signal ground (Black input terminals) and test point. For more details see Section 5.
I- Set FUNCTION switch to HIGH-PASS. Adjust P101 for zero dc at TP101. Adjust P301 for zero dc at TP301.
II- Set FUNCTION switch to LOW-PASS. Adjust P203 for zero dc at TP301.
OUTPUT terminals
Shorting link on front or rear
OUTPUT LOOP
DC LEVEL adjust TP301 & P301
INPUT LOOP
DC LEVEL adjust TP101 & P101
LOW PASS
DC LEVEL adjust P203
Line Fuse
1 1/2A Slo/115V - 3/4A Slo/230V
CAUTION: Do not overfuse
INPUT terminals
POWER REQUIREMENT
115/230V 50-400cps.
Normally wired for 115V
For 230V operation:
— Remove jumpers 1-2 & 3-4 on T401.
— Add jumper 2-3.
POWER ON/OFF Switch
INPUT terminals
GAIN 0db, 20db Switch
Max input:
Band-Pass & High-Pass
0db - 10 volts rms
20db - 1 volt rms
dc component 400 volts
Max input:
Low-Pass & Band-Reject
0db - 15V, peak ac plus dc
20db - 1.5V, peak ac plus dc
HIGH PASS SECTION
LOW PASS SECTION
OUTPUT terminals
Max output - 10 volts rms
2 ma. rms
Output Impedance: 50Ω approx.
For floating output:
Remove rear shorting link to ⏚
Set FUNCTION switch for:
LOW PASS
Set Low-Pass SECTION for:
CUTOFF
HIGH PASS
Set HIGH-PASS SECTION for:
CUTOFF
BAND PASS
Set HIGH-PASS SECTION for:
LOW CUTOFF
Set LOW-PASS SECTION for:
HIGH CUTOFF
BAND REJECT
Set LOW-PASS SECTION for:
LOW CUTOFF
Set HIGH-PASS SECTION for:
HIGH CUTOFF
BYPASS
INPUT terminals tied directly to OUTPUT terminals

Figure 7. Controls and Connections

e. Set desired cutoff frequencies by means of the MULTIPLY DIAL BY switches and the CUTOFF FREQUENCY dials.

NOTE

For operation in the band-pass mode, the left-hand MULTIPLY DIAL BY switch and CUTOFF FREQUENCY dial are used to select the low cutoff frequency, and the right-hand controls select the high cutoff frequency However, for operation in the band-reject mode, the right-hand controls select the low cutoff frequency and the left-hand controls select the high cutoff frequency.

In the high-pass mode only, the left-hand frequency controls (High-pass Section) are used. The right-hand frequency controls (Low-Pass Section) are inoperative and can be ignored.

In the low-pass mode only, the right-hand frequency controls (Low-Pass Section) are used and the other frequency controls are inoperative.

f. Throw POWER switch to ON.

2.6 GAIN AND PHASE CURVES

It is often desirable to determine a complete gain and phase characteristic for a particular Filter mode and frequency settings in order to predict performance in advance of taking actual readings. The gain and phase characteristics of the Filter for any one of the four operating modes can be plotted from the curves shown in Figure 5 and Figure 8.

BAND-PASS MODE

The gain at any frequency is the sum of the gains (in decibels) of the high and low cutoff attenuation curves. For example, as shown in Figure 5, if the cutoff frequencies are separated by a factor of four, the high cutoff frequency is at $f/f_H = 1$, the mid-band frequency (geometric mean of high and low cutoff frequencies as shown in Figure 3) is at $f/f_H = 0.5$, and the mid-band gain is plus 0.75 db. The low cutoff frequency is at $f_L/f = 1$, the mid-band frequency is at $f_L/f = 0.5$, and mid-band gain is plus 0.75 db. The total mid-frequency gain is then plus 1.5 db. The gain at the high cutoff frequency is minus 3 db due to the low-pass section ($f/f_H = 1$), and plus 0.3 db due to the high-pass section ($f_L/f = 0.25$), resulting in a total gain of minus 2.7 db. Also, the gain at the low cutoff frequency is minus 2.7 db because the two attenuation curves are symmetrical about the mid-band frequency. As many other points as required can be similarly obtained from Figure 5.

The phase angle at any frequency is the sum of the angles due to the high- and low-pass filter sections. For example, as shown in Figure 8, if the cutoff frequencies are separated by a factor of four, the phase angle due to the low-pass section is approximately minus 180° at the high cutoff frequency ($f/f_H = 1$), minus 80° at mid-band ($f/f_H = 0.5$) and minus 30° at the low cutoff frequency ($f/f_H = 0.25$). The phase angle due to the high-pass section is

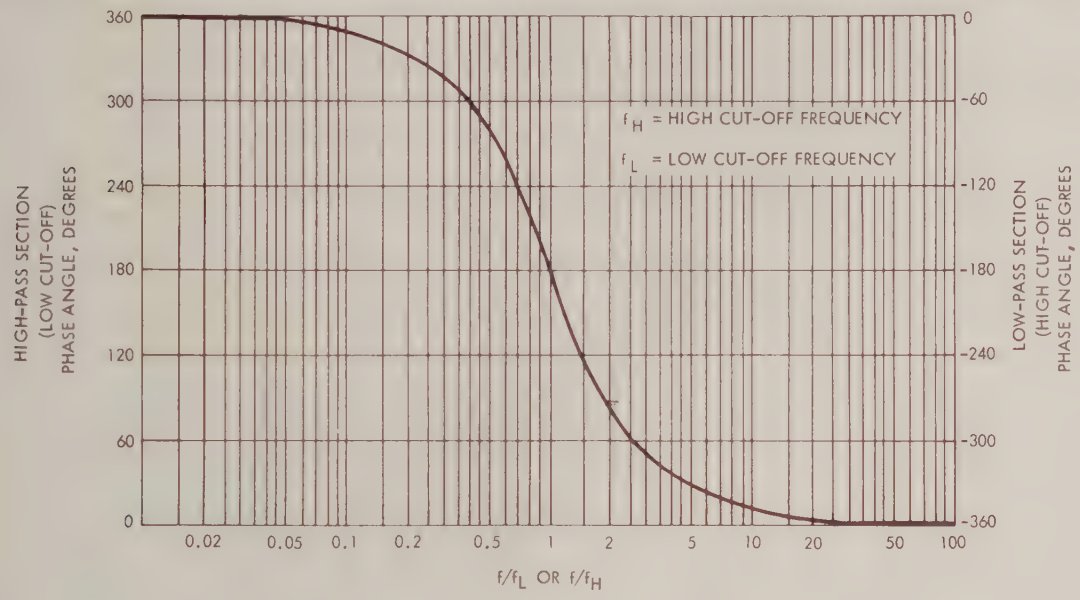

Figure 8. Normalized Phase Characteristics

approximately plus 30° at the high cutoff frequency ($f/f_L = 4$), plus 80° at mid-band ($f/f_L = 2$), and plus 180° at the low cutoff frequency ($f/f_L = 1$). Therefore, the total phase angle is minus 150° at the high cutoff frequency, zero at mid-band, and plus 150° at the low cutoff frequency. Phase angles at other frequencies can be similarly obtained from Figure 8.

An example of Filter gain and phase characteristics in the band-pass mode for a frequency separation factor of 10 is shown in Figure 9. The low cutoff frequency is at 10 kc, the mid-band frequency at 31.6 kc (geometric mean of high and low cutoff frequencies), and the high cutoff frequency is at 100 kc.

BAND-REJECT MODE

When the Filter is used in the band-reject mode, the gain and phase of the individual sections is determined in the same manner as that used for the band-pass mode. These gains and phase angles due to the high- and low-pass sections cannot be added directly to obtain total gain and phase angle. First, it is necessary to expand the vector (magnitude and phase) obtained from the characteristic curves of the low-pass section into its real and imaginary components. These components must then be added arithmetically to those obtained from the curves of the high-pass section. The resulting components are then converted into a magnitude and phase angle.

HIGH-PASS OR LOW-PASS MODE

When the Filter is used in the high-pass or low-pass mode, the gain can be plotted from Figure 5 by considering either one of the abscissas labeled "f_H/f" or "f_L/f". The desired cutoff frequency is at unity, and the curve is symmetrical to the one shown about the unity point on the abscissa. Phase angle is obtained from Figure 8 by using either scale on the abscissa and the left-hand ordinates.

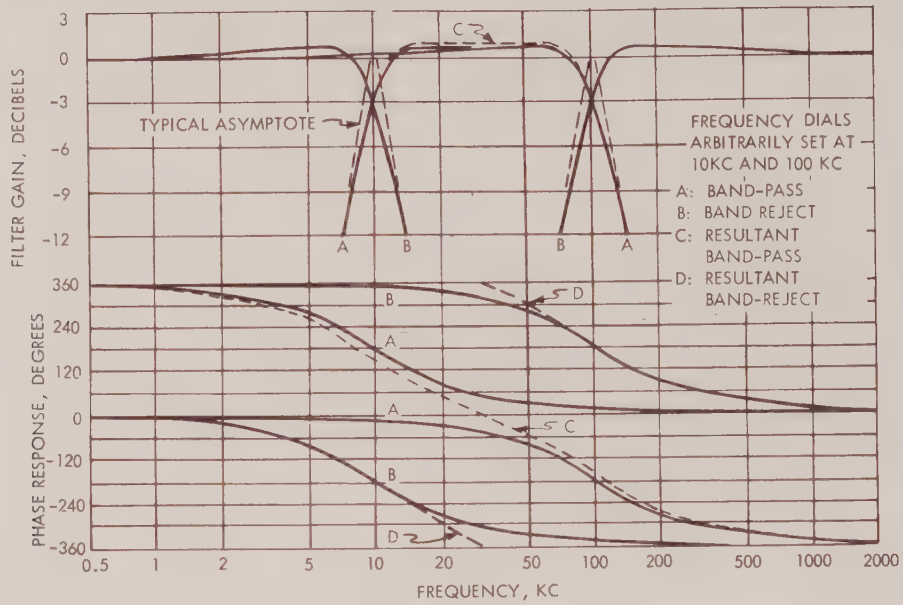

Figure 9. Gain and Phase Characteristics

SECTION 3

CIRCUIT DESCRIPTION

3.1 INTRODUCTION

As shown in the Simplified Diagram, Figure 2, the Filter consists basically of an input amplifier, a high-pass filter section, a low-pass filter section and an output amplifier. The Schematic Diagram of the Filter, Figure 17, is attached to the rear cover. The bold lines on the Filter schematic show the main signal paths, while the dash lines indicate feedback signal paths.

3.2 DETAILED DESCRIPTION

INPUT AMPLIFIER

The input amplifier is a direct coupled three-stage feedback amplifier which provides a low impedance driving source to the following RC circuits. The gain of the input amplifier may be varied by means of a front panel switch so that the Filter has a gain of unity or 20 db. The first stage, V1, is a balanced amplifier with the input signal applied to one grid and the feedback signal to the other. The second stage, 1/2 of V2, is an amplifier which drives the third stage, 1/2 of V2, a cathode follower. Part of the output of the cathode follower is fed-back to the first stage.

HIGH-PASS SECTION

This section includes four cascaded RC filter sections coupled by cathode follower isolating stages. Each RC filter section has a critical or cutoff frequency (identical for each section) that is determined by the particular values of R and C. Each section attenuates all frequencies below the cutoff frequency at the rate of 6 db/octave and passes all frequencies above it. The cutoff frequency of all four sections is adjusted simultaneously by the ganged MULTIPLY DIAL BY switch (S201A, B, C, and D) and the ganged CUTOFF FREQUENCY potentiometers (P201A, B, C, and D). The four cascaded RC stages produce the 24 db/octave attenuation characteristic.

Depending on the frequency range desired, any one of six capacitors can be selected by the MULTIPLY DIAL BY switch. The CUTOFF FREQUENCY dial adjusts the value of resistance in the RC circuit to obtain a particular frequency within the selected range.

LOW-PASS SECTION

The low-pass section also consists of four cascaded RC filter sections coupled by isolating cathode follower circuits. The cutoff frequency (identical for each section) is determined by the selected values of R and C. All four sections are adjusted simultaneously by the use of ganged MULTIPLY DIAL BY switch (S202A, B, C, and D), and ganged CUTOFF FREQUENCY potentiometers (P202A, B, C, and D). All frequencies below the cutoff frequency are passed while frequencies above the cutoff frequency are attenuated at the rate of 6 db/octave per section. The cascaded combination of the four RC sections results in a total attenuation rate of 24 db/octave.

OUTPUT AMPLIFIER

The output amplifier is a direct coupled three-stage feedback amplifier which provides a low impedance driving source for the Filter output. The first stage, V7, is a balanced amplifier with the signal applied to one grid and feedback to the other. The second stage, 1/2 of V8, is an amplifier which drives the third stage, 1/2 of V8, a cathode follower. Part of the output of the cathode follower is fed back to the first stage.

SIGNAL PATH

The signal path in any of the five operating modes is determined by the position of FUNCTION switch, S203. This is a rotary switch with four wafers. The switching action, as shown in Figure 2, has been simplified for convenience in following the signal paths.

BAND-PASS MODE

When the Filter is operated in the band-pass mode, the high-pass section and low-pass section are connected in series. With the FUNCTION switch on BAND PASS, the input signal is fed through wafer 1F of S203, to the input amplifier. It is then coupled from the output of V2 to the input of the high-pass section. After passing through S201A the signal is coupled to the first cathode follower by S203, wafer 1B. The output of the high-pass section is connected to the input of the low-pass section by wafers 2F and 3B of S203.

The output of the low-pass section is coupled to the output amplifier through S203, wafer 4B. The output loop is connected to the output terminals through wafer 4F of S203.

BAND-REJECT MODE

When the Filter is operated in the band-reject mode, the high-pass section and the low-pass section are connected in parallel. With the FUNCTION switch S203 in the BAND-REJECT position, the input signal is fed through S203, wafer 1F to the input amplifier. From the output of V2, it is coupled to the low-pass section through wafers 1B and 2F, and to the input of the high-pass section, S201A. Through wafer 1B the signal is connected to the first cathode follower of the high-pass section. The output of the high-pass and low-pass sections are added together through R226 and R227 and fed to the output amplifier through wafer 4F. The signal is then connected to the output terminals through wafer 4F.

HIGH-PASS MODE

When the Filter is operated in the high-pass mode, only the high-pass section is used. With the FUNCTION switch S203 on HIGH PASS, the input signal is fed through wafer 1F to the input amplifier. From the output of V2, the signal is fed to the input of the high-pass section S201A. The signal is connected to the first cathode follower through wafer 1B. The output of the high-pass section is connected to the input of the output amplifier through wafer 3F. The signal is connected to the output terminals through wafer 4F.

LOW-PASS MODE

When the Filter is operated in the low-pass mode, only the low-pass section is used. With the FUNCTION switch S203 on LOW PASS, the input signal is fed through wafer 1F to the input amplifier. From the output of V2, the signal is connected to the low-pass section through wafers 1B and 2F. The output of the low-pass section is connected to the output amplifier through wafers 4F and 4B. The signal is connected to the output terminals through wafer 4F.

BY-PASS MODE

The by-pass mode has been provided as a convenient way to remove the Filter from the circuit. With the FUNCTION switch in the BY PASS position, the INPUT terminals are connected directly to the OUTPUT terminals.

POWER SUPPLY

The Model 335 has two regulated dc supplies, one for high voltage and one for heater voltage.

The high voltage supply consists of three sections: an unregulated supply using a full wave rectifier tube V9, whose output is filtered by a capacitor input, single section pi filter C401, C402 and L401; an electronically regulated supply, consisting of tubes V10, V11 and V12 which provides regulated 350 volts; and a center-tap regulator V13, V14 and V15. The Regulated Supply functions in a conventional manner. The Center Tap Regulator adds the negative and positive of the 350 volt Regulated Supply through two equal

resistors, R411 and R412, and compares the sum with ground in the differential amplifier V15. Since the comparison resistors are equal and the reference voltage is ground, the regulated 350 volts is divided into two equal and opposite voltages, plus 175 and minus 175 volts with respect to ground.

The heater supply consists of bridge-connected rectifiers CR401 to CR404 and a filter capacitor C415 which provides an unregulated 34 volts to the transistor regulator Q401 and Q402. The reference voltage, obtained from the minus 175 volt regulated output, maintains a fixed voltage at the base of Q401 through the emitter follower Q402. Any deviation in output voltage due to line variations is compensated for by the regulating action of Q401.

3.3 PRINCIPLES OF OPERATION

LOW-PASS FILTER SECTION

As shown in the Simplified Schematic Diagram, Figure 2, the Filter consists of an input amplifier, a high-pass filter section, a low-pass filter section and an output amplifier. The low-pass filter section consists of two similar low-pass circuits connected in series. The simplified schematic of one low-pass circuit is shown in Figure 10.

A portion of the output signal GE_2 is fed back to the first capacitor C1. If both capacitors and resistors are equal, the circuit has a transfer function of:

$$\frac{E_2}{E_1} = \frac{1}{j^2\omega^2 R^2C^2 + j\omega RC\,(2-G) + 1}$$

At the cutoff frequency where $j^2\omega^2 R^2C^2 + 1 = 0$ or $\omega_{co} = 1/RC$ the gain of the circuit becomes $1/(2-G)$. The peaking of the response curve for three different values of the peaking factor A is shown in Figure 11, where $A = 1 - G/2$.

The middle curve is used in the Filter and is obtained by setting the peaking factor A to approximately 0.6 which corresponds to a gain G of approximately 0.8. This results in a gain of approximately minus 1.5 db at the cutoff frequency, and an attenuation slope of 12 db/octave for each low-pass circuit. The two similar circuits combine to achieve a gain of minus 3 db at the cutoff frequency and an attenuation slope of 24 db/octave.

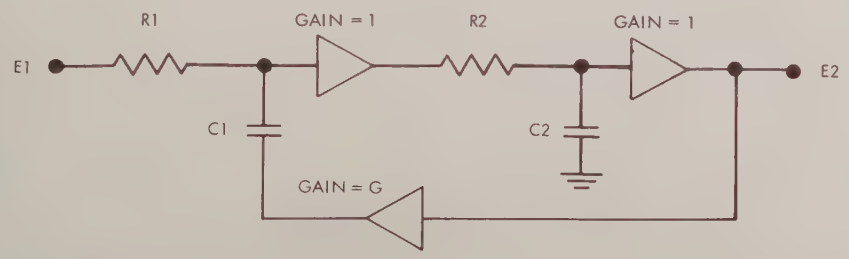

Figure 10. Simplified Low-Pass Circuit

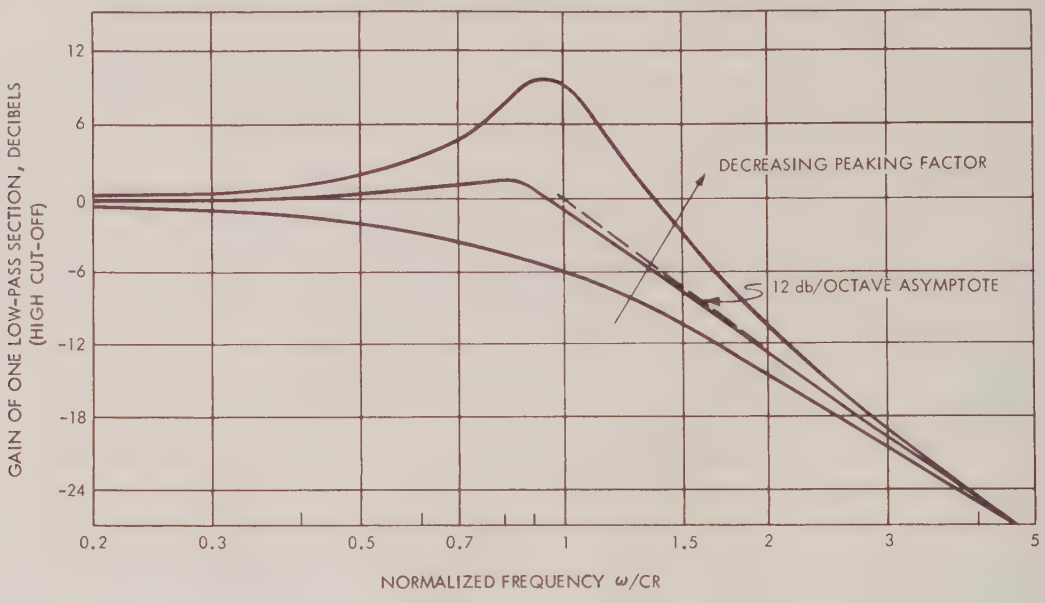

Figure 11. Effect of Corner Peaking

HIGH-PASS FILTER SECTION

The high-pass filter section is composed of two similar high-pass circuits. The basic circuit is shown in Figure 12.

The feedback signal GE_2 is fed to the first amplifier through resistor R1. If both capacitors and resistors are equal, the circuit has a transfer function of:

$$\frac{E_2}{E_1} = \frac{j^2\omega^2 R^2C^2}{j^2\omega^2 R^2C^2 + j\omega RC\,(2-G) + 1}$$

At the cutoff frequency where $\omega_{co} = 1/C\,R$ the gain of the circuit becomes $1/(2-G)$.

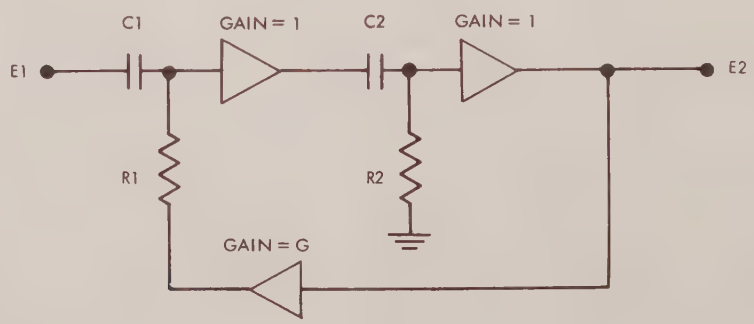

Figure 12. Simplified High-Pass Circuit

The response curves of one high-pass circuit are symmetrical to the curves shown in Figure 11 about the axis of normalized frequency of unity. The middle curve is used in the Filter and is obtained by setting the peaking factor A to approximately 0.6 giving a gain of approximately minus 1.5 db at the cutoff frequency, and an attenuation slope of 12 db/octave for each high-pass circuit. The two similar circuits combine to achieve minus 3 db at the cutoff frequency and an attenuation slope of 24 db/octave.

EFFECTS OF PEAKING FACTOR

Choosing a peaking factor of approximately 0.6, obtained by selecting a gain of approximately 0.4 in the feedback amplifier, results in relatively small (0.75 db) peaks in the attenuation curve, but reduces the corner frequency attenuation by 9 db from that obtained from four independent RC sections with unity peaking factor. For most applications, the Filter is superior because of the higher gain near the corner frequencies. Figure 13 shows a typical band-pass characteristic for a low cutoff frequency of 40 cps, and a high cut-off frequency of 160 cps. The response of the Filter is shown by the solid curve, and the response of a filter without a peaking feedback loop is shown by the dash curve.

TRANSFER FUNCTIONS

The transfer functions (output voltage over input voltage) for the four modes of operation can be expressed as follows:

BAND-PASS: $$\frac{\omega^4 T_1^4}{(1 + 2j A\omega T_1 - \omega^2 T_1^2)^2 (1 + 2j A\omega T_2 - \omega^2 T_2^2)^2}$$

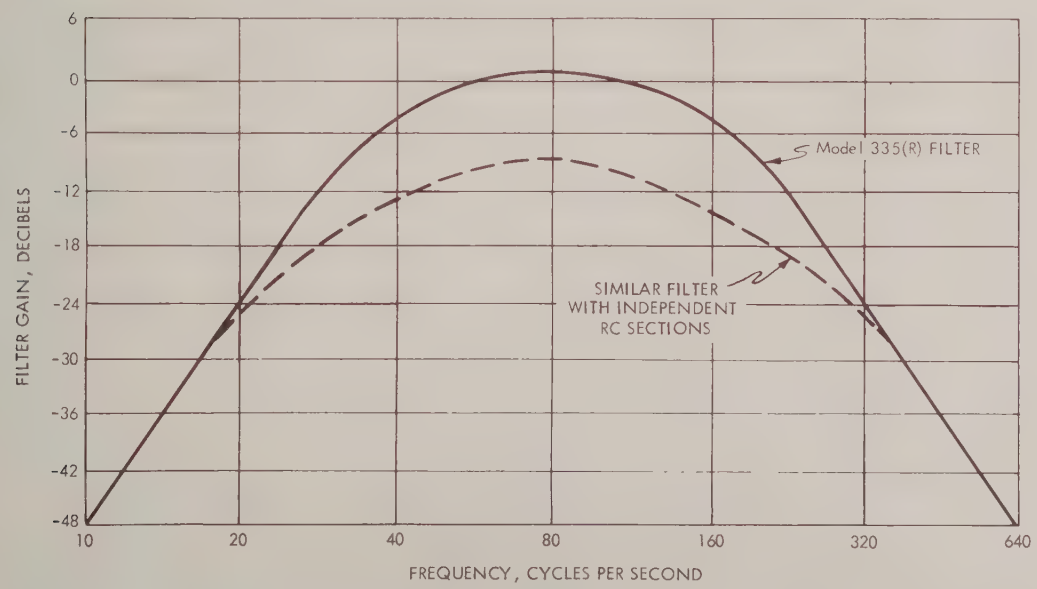

Figure 13. Effect of Corner Peaking on Pass-Band

BAND-REJECT: $$\frac{1}{(1 + 2j A\omega T_1 - \omega^2 T_1^2)^2} + \frac{\omega^4 T_2^4}{(1 + 2j A\omega T_2 - \omega^2 T_2^2)^2}$$

HIGH-PASS: $$\frac{\omega^4 T_1^4}{(1 + 2j A\omega T_1 - \omega^2 T_1^2)^2}$$

LOW-PASS: $$\frac{1}{(1 + 2j A\omega T_2 - \omega^2 T_2^2)^2}$$

where the low cutoff frequency is $1/2\ \pi T_1$, and the high cutoff frequency is $1/2\ \pi T_2$. The value of the peaking factor A, which is normally unity for filters composed of independent resistance-capacitance elements, is fixed at approximately 0.6. This value produces gain-peaks of approximately 0.75 db and reduced attenuation at the cutoff frequencies compared to the attenuation of a filter with unity peaking factor.

SECTION 4

MAINTENANCE

4.1 INTRODUCTION

If the Filter is not functioning properly, the following procedure should facilitate locating the source of trouble.

Removal of the Filter from its cabinet will allow easy access to its components. To take the unit from the cabinet, remove the two screws from the bottom rear of the cabinet, and the four nickel plated screws from the front panel.

Major components of the Filter may be located by reference to Figures 14 and 15 (see Section 5).

4.2 TUBE COMPLEMENT CHECK

The most likely source of trouble in the Filter is the electron tubes, since they have an inherently shorter life than any of the other components.

Connect the Filter to the proper line voltage (115V or 230V), turn it on, and check that the correct tube is inserted securely in each socket. The correct tube type is marked on the chassis adjacent to each socket. After a short

warmup time, note that each tube heater is lighted and that the reference tube, V11, is operating properly, as indicated by an orange glow in the tube.

If any of the tubes fail to light, they should be replaced. It should be noted that under certain conditions, because of the type of heater connections used in this instrument, if one of the tubes fails, from one to three other tubes may be affected. Table 1 shows which tubes will be affected this way.

TABLE 1

HEATER CONNECTIONS

Heater String	Tubes Involved
1	V1, V2, V7, &V8
2	V3 & V4
3	V5 & V6
4	V12 & V15
5	V13 & V14

NOTE

On units with serial number 205 and above, a fuse, F403, (1.5A, fast blow) has been incorporated to protect the REGULATED DC HEATER SUPPLY from short circuits. If the dials are not illuminated and all tubes except V9 and V10 fail to light, this fuse should be checked. The fuse is located under the chassis toward the rear of the unit.

If this initial tube check does not locate the source of trouble, new tubes may be substituted, one at a time, until the faulty tube is found.

4.3 FUSE FAILURE

A fuse F401 (1.5A) for 115V operation or F402 (0.75A) for 230V operation, located on the rear of the chassis, is used in the primary circuit of the power transformer to protect the power supply components from short circuits and overloads. The rating of this fuse was selected for proper protection of the instrument, and it should be replaced with one of the same type and rating.

If a fuse failure is detected, the following procedure is recommended before replacing the fuse.

a. Check for a faulty rectifier tube, V9 (6AX5-GT).

b. Check for short circuits in C401 and C402. This may be done by connecting an ohmmeter directly across the capacitor terminals with the Filter turned off. The reading here should be at least 20,000 ohms.

c. Check for shorts in the regulated voltage busses. With the exception of power transformer leads, filter choke leads, and spaghetti-covered leads, all red wires in the unit are tied to the plus 170V buss, all grey wires to the minus 170V buss, and all black wires to ground. If a short exists between one of these busses and ground, or between the two busses, all tie points connected to the shorted buss should be checked.

d. Check the dc resistance of the power transformer primary. This should be approximately 2.5 ohms in the 115V connection, and approximately 10 ohms in the 230V connection. A much lower resistance probably indicates a shorted primary.

For units with serial number 205 and above, refer to special note about F403 on page 21.

4.4 POWER SUPPLY

If the Filter is not functioning when the correct line voltage is applied and illuminated dials indicate that it is being powered, the internal power supplies should be checked.

If the CENTER TAP REGULATOR is not functioning properly, it may upset the operation of the other supplies, and therefore should be checked first. When the CENTER TAP REGULATOR is operating properly, it will divide the output of the REGULATED SUPPLY into two voltages of equal magnitude with respect to ground. These voltages are normally plus 170V and minus 170V. If the two voltages are of equal magnitude, even though they may not be the correct value, the CENTER TAP REGULATOR is working properly.

If an unbalance exists in the CENTER TAP REGULATOR, the circuitry connected with V13, V14, and V15 should be checked. This is basically a direct coupled amplifier, and the faulty component should be found at the point in the loop where an error signal is blocked in its attempt to correct the malfunction.

As an example of this method of trouble-shooting, let us assume that an unbalance exists in which the magnitude of the negative supply voltage is greater than that of the positive supply. This will cause the grid of V15 (pin 7) to assume a value more negative than its nominal zero. The plate of V15 (pin 1) will then become more negative than normal (see V & R chart, Figure 17), as will the grid (pin 7) of V14. This will lower the plate (pin 1) of V14, which will in turn lower the grids (pins 2 & 7) of V13 and cause a decrease in the current through this tube. This decrease in current will then act to balance the magnitude of the two outputs. Using this type of signal tracing, the faulty component will usually be found at the point in the circuit where the error signal is blocked in its attempt to correct the malfunction. As an example of the blocking of an error signal, let us assume that in the preceeding case, V14 had been defective. If this were so, when the grid (pin 7) went below its nominal value, the plate (pin 1) could not respond by going more negative than normal, and the error signal would be blocked at this point.

The UNREGULATED SUPPLY voltage is taken from the cathode of the rectifier tube, V9, filtered by C401, C402, and L401, and delivered to the REGULATED SUPPLY. The UNREGULATED voltage may be measured between pin 5 of V10 and ground. With normal line voltage (115V or 230V) applied to the unit, the UNREGULATED SUPPLY should read approximately 340 volts.

If the UNREGULATED voltage deviates considerably from its nominal value, the rectifier, V9, should be replaced. If this does not change the voltage level, the total current drain should be checked. This may be done by measuring the voltage drop across L401. This should normally read about 15 volts DC. A reading appreciably higher than this indicates that excessive current is being drawn by the Filter. This excessive current could be due to a low resistance path in C402, or to a malfunction in the main circuitry of the instrument.

Under normal conditions, the REGULATED SUPPLY delivers 340 volts to the CENTER TAP REGULATOR, which then divides it into equal plus and minus supplies with respect to ground. If the REGULATED SUPPLY is not delivering its normal 340V (or plus 170V and minus 170V with respect to ground), the circuitry associated with V10, V11, and V12 should be checked. This involves essentially a voltage reference, a direct coupled amplifier, and a series regulator. If the REGULATED SUPPLY is not working properly, the faulty component will usually be found at the point in the loop where an error signal is blocked in its attempt to correct the malfunction. This trouble shooting method has been previously discussed under the section on the CENTER TAP REGULATOR.

The REGULATED DC HEATER SUPPLY provides approximately 24 volts for the various heater strings in the Filter. If the supply is not providing the proper voltage, Q401, Q402, and their associated circuitry should be checked. The regulator in this case is basically a series regulator, and the same type of trouble shooting method described under the CENTER TAP REGULATOR may be used here.

4.5 SIGNAL TRACING ANALYSIS

If the power supplies appear to be working properly, and the Filter is still not functioning, the following SIGNAL TRACING ANALYSIS should locate the area of the malfunction.

Set the FUNCTION switch to BAND PASS, the GAIN switch to 0 DB, the high pass frequency to 0.02 cps, and the low pass frequency to 20 kc. Apply a 200 cps, 10V rms, sine wave signal to the INPUT terminals of the Filter. When the instrument is operating properly, this signal will pass through the Filter unchanged, and will appear at the OUTPUT terminals with the same amplitude as at the input. If this test signal does not appear correctly at the output, the area of the malfunction may be localized by determining where in the instrument the signal first deviates from normal.

Table 2 shows various test points with their correct signal levels. If a test point is found whose signal level differs appreciably from the correct value, all of the components, wiring, and voltage and resistance readings to ground

TABLE 2

TEST POINT VOLTAGES

FUNCTION switch: BAND PASS HIGH PASS frequency: 0.02 cps LOW PASS frequency: 20 kc INPUT: 10v rms, 200 cps, sine wave		
TEST POINT		CORRECT SIGNAL LEVEL (volts)*
TUBE	PIN	
V1	2	10
V1	1	0.25
V2	6	29
V2	8	28
V3	8	11
V3	3	10.5
V4	8	10.5
V4	3	10.5
V5	8	10
V5	3	8
V6	8	8
V6	3	6.8
V7	1	0.1
V8	6	10.5
V8	8	10

*Variations of up to ± 20% in all readings can be expected.

(see V & R chart, Figure 17) associated with the circuitry preceeding the test point should be checked.

These test points basically trace the signal through the entire Filter, and they should be checked in the order given. Under the conditions specified, the test signal is well within the pass band of the Filter, and should not be affected by small changes in either the high or low cutoff frequencies.

4.51 INPUT AMPLIFIER

The input signal is applied through a coupling capacitor and to the grid of the first stage. Because of the feedback applied to this stage, the signal is greatly reduced and the 10V input becomes approximately 0.25V at the first plate (V1, pin 1). This is then applied to the grid of the second stage where it is amplified to become approximately 29V at the plate of the second stage (V2, pin 6). The signal then passes through a cathode follower where it is

reduced slightly in amplitude to approximately 28V at pin 8 of V2. The signal then passes through the FUNCTION switch, after which it goes on to the high pass section.

4.52 HIGH PASS SECTION

The high pass section consists of four cathode followers and four RC tuning circuits. The output of the first cathode follower (V3, pin 8) should be about 11V, and that of the second, third, and fourth, about 10.5V. After the high pass section, the signal again goes to the FUNCTION switch, and then to the low pass section.

4.53 LOW PASS SECTION

The low pass section also consists of four cathode followers and four RC tuning circuits. The output of the first cathode follower (V5, pin 8) should be about 10V, that of the second (V5, pin 3) about 8V, the third (V6, pin 8) about 8V, and the fourth (V6, pin 3) about 6.8V. After the low pass section the signal again goes to the FUNCTION switch and then to the output amplifier.

4.54 OUTPUT AMPLIFIER

The output amplifier is very similar to the input amplifier and functions in much the same manner. The signal is attenuated in the first stage to become approximately 0.1V at pin 1 of V7. The second stage then amplifies the signal to about 10.5V at pin 6 of V8. The signal then goes through a cathode follower whose output (V8, pin 8) should be approximately 10V. After passing through the FUNCTION switch once more, the signal then goes to the OUTPUT terminals.

4.6 SWITCHING

If the Filter works properly in the BAND PASS mode, but not in other modes of operation, the trouble probably lies in the FUNCTION switch, S203, or its associated wiring or components.

If the Filter works on one MULTIPLY DIAL BY band and not another, the trouble is probably in the switch (S201 or S202), its associated wiring, or in one of the tuning capacitors selected by this switch.

4.7 TUNING CIRCUITS

The range-determining capacitors associated with the MULTIPLY DIAL BY switches S201 and S202 are specially selected for close capacitance tolerance. All capacitor values fall within ±5% of the specified value, but in order to maintain accurate frequency calibration over the entire dial range and also between decade ranges, the capacitors are matched to within ±2% of each other and within ±2% in decade ratios. For replacement purposes, a capacitor within ±1% of the specified value can be used with negligible effect on overall calibration accuracy.

If more than one capacitor on a particular range is to be changed, it is recommended that several other capacitors on the switch be carefully measured on a capacitance bridge to determine the average percentage deviation

from the nominal value. Any capacitors except those used on the highest frequency range (lowest values) can be measured to determine the tolerance. Replacement can then be made with capacitors of the exact value, and calibration will not be impaired. If exact replacement values are not readily available, a slightly lower value can be paralleled with small capacitors to build up to the required value.

Each of the two CUTOFF FREQUENCY dial variable resistance elements, P201 and P202, consists of four potentiometers ganged together with a gear assembly and coupled to the hand engraved dial. The variable resistance elements are adjusted by series and shunt trim resistors to match the overall capacitance tolerance used in a particular instrument. The trim resistors and the angular orientation of the variable resistors are carefully adjusted at the Factory for proper tracking and calibration over the entire range of the dial. Should it be necessary for any reason to replace more than one of the variable resistors, we strongly recommend replacement of the entire assembly. The assemblies are available from the Factory, complete with the matching individually-calibrated dial. Refer to Section 6, Parts List, for ordering information. The trim resistors and the variable resistor shaft orientation can be adjusted, if necessary, by following carefully the instructions in Paragraph 5.4, Section 5.

SECTION 5

CALIBRATION AND ADJUSTMENT

5.1 INTRODUCTION

The following procedure is provided for the purpose of facilitating the calibration and adjustments of the Filter in the field. The steps outlined follow very closely the operations which are performed on the instrument by our Final Test Department, and strict adherence to this procedure should restore the instrument to its original specifications. It should be noted that some of the tolerances given in this procedure are much tighter than our general specifications. This is to ensure, in test, that all general specifications are met with adequate safety factor. These nominal tolerances, therefore, should not be used for purposes of accepting or rejecting the instrument. If any difficulties are encountered, or if any questions arise which are not covered by this procedure, please consult our Factory Service Department.

5.2 DETAILED TEST PROCEDURE

GENERAL

a. All dc voltage measurements should be made with a VTVM, and made with respect to ground (chassis), unless otherwise specified. Signal ground should be tied to chassis throughout the procedure.

b. All measurements should be made with a line voltage having less than 1% distortion.

c. Give the instrument a thorough visual inspection, looking particularly for oil leaks, discoloration of the chassis, component panels, or components, and loose or broken wires, poor solder connections, etc.

d. Check that all tubes are seated firmly in the correct sockets and that all heaters light.

e. Check operation of POWER swtich.

f. Check that wires do not touch the gears and that the dials rotate smoothly.

g. For location of adjustments and test points referred to in this procedure, refer to Figures 14 and 15.

h. If the following tests show discrepancies and the remedy is not apparent, refer to maintenance, Section 4.

TEST EQUIPMENT REQUIRED

a. Audio Oscillator or Oscillators - capable of supplying at least 10 volts rms from 0.02 cps to 100 kc and at least 1 volt rms from 100 kc to 1 mc, with frequency calibration accuracy better than ± 1% and distortion less than 0.1% over most of the range.

b. Oscilloscope - having direct coupled horizontal and vertical amplifiers with equal phase characteristics from 0.02 cps to 20 kc and vertical sensitivity of at least 50 mv/cm.

c. AC VTVM - frequency response, 10 cps to 1 mc; full scale sensitivity from 10 mv to 10 volts rms with db scale; input capacitance should be less than 20 $\mu\mu$f.

d. DC VTVM - capable of reading up to 500 volts dc.

e. AC Voltmeter - to monitor line voltage.

f. Variable Auto-transformer - to adjust line voltage.

g. 45 Volt Battery - to provide dc input.

h. Resistance Bridge - accuracy of at least 1%.

POWER SUPPLY DC VOLTAGE AND RIPPLE TEST

Before proceeding with the Detailed Test Procedure, Table 3, the following dc voltages and ripple should be checked to ensure the proper operation of

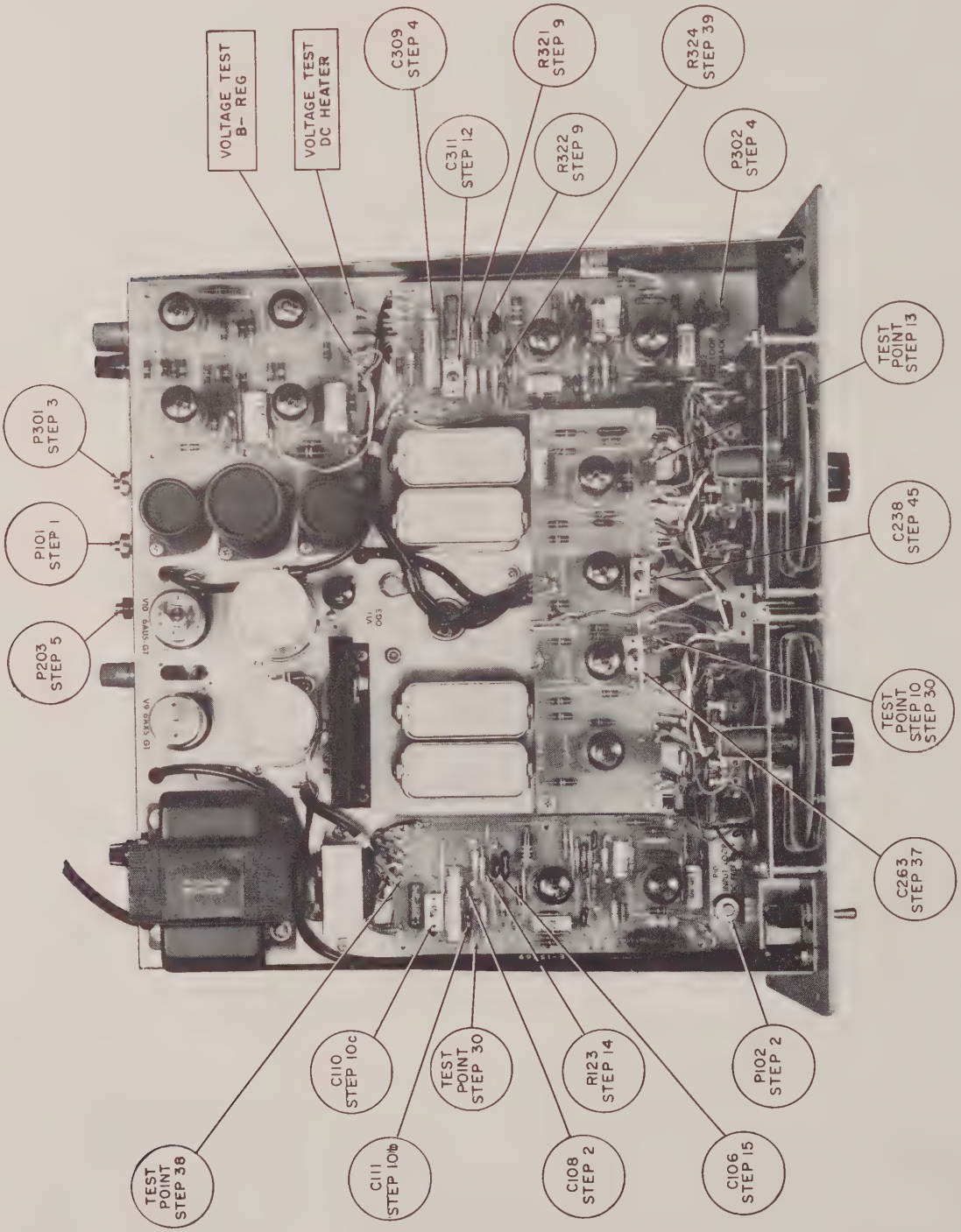

Figure 14. Filter Chassis, Top View

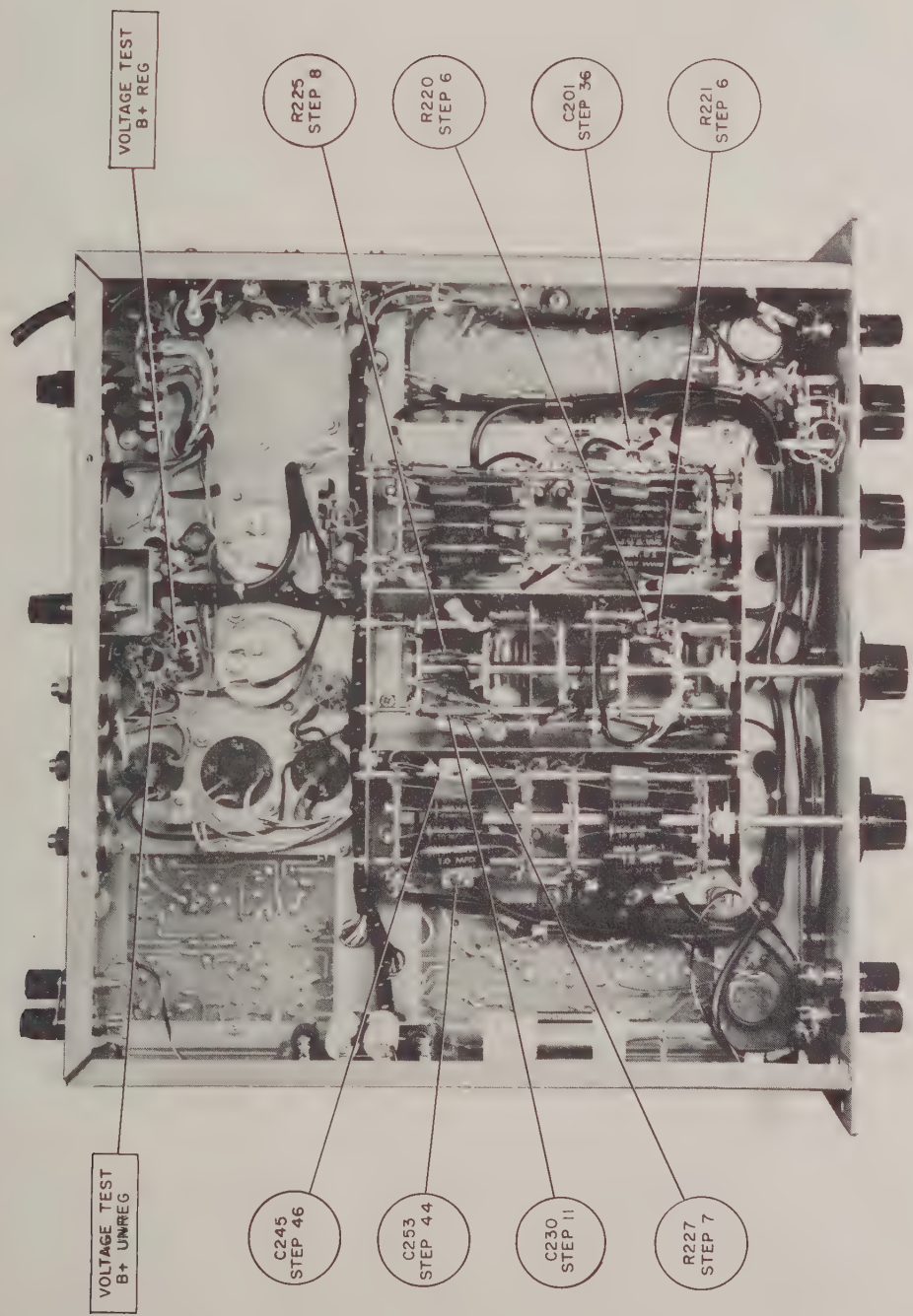

Figure 15. Filter Chassis, Bottom View

the Filter internal power supplies. These voltages should be checked with the Filter operating in the Band Pass mode at 115 volts line voltage.

	Voltage Test Point	Tolerance
a.	B plus unregulated, plate of V10	315 volts dc ± 20%
b.	B plus regulated, cathode of V10	175 volts dc ± 20%
c.	B minus regulated, terminal 4 of PC401	-175 volts dc ± 20%
d.	DC heater supply, terminal 1 of PC401	24 volts dc ± 20%
e.	B plus ripple; measure a-c ripple on the cathode of V10 with an oscilloscope.	Less than 50 mv P. P.

TEST PROCEDURES

Table 3 contains Detailed Test Procedures to check Filter performance. The procedures are to be performed in the given order (1 through 54). Throughout the procedures, "low-pass" is abbreviated "LP", "high-pass" is abbreviated "HP", "Band-pass" is abbreviated "BP", and "band-reject" is abbreviated "BR". Note that LOW-PASS dial and multiplier refers to the right-hand frequency dial and band multiplier switch, and that HIGH-PASS dial and multiplier refers to the left-hand frequency dial and band multiplier switch.

TABLE 3. DETAILED TEST PROCEDURE

STEP	PROCEDURE	Gain	Function	FREQUENCY SETTING				INPUT SIGNAL	
				HP Dial	HP Multiplier	LP Dial	LP Multiplier	Voltage	Frequency
1	Input loop dc level adj.	0 db	HP	--	--	--	--	Short	--
	Connect a dc voltmeter to TP101 (on rear chassis apron). Adjust P101, INPUT LOOP DC LEVEL pot., located on rear chassis apron for approximately zero volts.								
2	Input loop dc feedback adj.	0 db	HP	--	--	--	--	Short	--
	Adjust P102, INPUT LOOP DC FEEDBACK pot., located on top of chassis for zero ±.1 volt change on TP101 when the cathode of V2A is loaded with approximately 100,000 ohms.* If P102 had to be adjusted, recheck step 1. *This load can be applied from the plus side of C108 on PC101A to B minus (terminal No. 4 of PC401).								
3	Output loop dc level adj.	0 db	HP	--	--	--	--	Short	--
	Connect the dc voltmeter to TP301. Adjust P301, OUTPUT LOOP DC LEVEL pot., located on rear chassis apron for approximately zero volts.								
4	Output loop dc feedback adj.	0 db	HP	--	--	--	--	Short	--
	Adjust P302, OUTPUT LOOP DC FEEDBACK pot., located on top of chassis for zero ± .1 volt change on TP301 when the cathode of V8A is loaded with approximately 100,000 ohms.* If P302 had to be adjusted, recheck step 3. *This load can be applied from the plus side of C309 to B minus (terminal No. 4 of PC401).								
5A	Low pass dc level adj.	0 db	LP	--	--	--	--	Short	--
	After dc voltage settles down, adjust P203, LOW PASS DC LEVEL pot., located on rear chassis apron for approximately zero volts measured on TP301. If P203 had to be adjusted, recheck step 3.								
5B	Band reject dc level adj.	0 db	BR	--	10	--	10	Short	--
	Adjust P204, BAND-REJECT DC LEVEL POT, located on rear chassis apron for a reading of approximately zero volts on TP301. If P204 had to be adjusted, recheck steps 3, 4, and 5A.								
6	LP-BP gain adj.	0 db	LP-BP	2	.01	20	1000	5.0	600 cps
	Connect an ac VTVM to the output of the Filter. Switch the Function from LP to BP and observe the output voltage change. Tolerance: less than ±0.5 db. If out of specifications, adjust the value of R220 or R221 with function switch in LP.								
7	LP-BR gain adj.	0 db	BR	2	1000-1	20	1000-1	5.0	600 cps
	Switch both multipliers to 1, and observe the output voltage change. Tolerance: less than ±0.5 db. If out of specifications, adjust the value of R227.								
8	HP-BR gain adj.	0 db	HP	2	1-.01	20	1-.01	5.0	600 cps
	Switch both multipliers to 0.01, and observe the output voltage change. Tolerance: less than ±0.5 db. If out of specifications, adjust the value of R225.								
9	Unity gain, 600 cps	0 db	HP	2	.01	20	.01	2.5	600 cps
	Check gain of Filter from input to output. Tolerance: zero ±1 db. If gain is low, shunt R322; if gain is high, shunt R321.								
10	Frequency response - Input loop	0 db	HP	2	100	20	1000	0.25	600 cps to 1 mc
A.	Connect an ac VTVM to terminal No. 9 of PC201. Adjust the input signal so that 0.25 volts is observed at this point. Keeping the input voltage constant, observe the voltage change on terminal No. 9 of PC201 as the frequency is increased to 100 kc. Tolerance: less than ± 1 db. NOTE: The following adjustments, parts B and C of this test, are dependent upon each other. Keep this in mind while proceeding. Both steps B & C may need to be done a number of times before optimum settings of the trimmers are reached.								
B.	Sweep the Oscillator from 100 kc slowly to 1 mc and observe the voltage change on terminal No. 9 of PC201, ensuring that the input voltage is kept constant. Adjust capacitor trimmer C110 or change the value of capacitor C111, if necessary, so that the voltage does not peak more than 1.0 db at any frequency and is less than 3 db down at 1 mc. In order to increase the signal at 1 mc, it may be necessary to have about a 0.5 db peak at approximately 500 kc.								
C.	Switch the HP multiplier to 1000 and recheck the voltage vs. frequency from 100 kc to 1 mc as in part B above. Capacitor trimmer, C110, may need to be readjusted so that the voltage does not peak more than 1 db and is less than 3 db down at approximately 900 kc. If C110 is readjusted, repeat part B as noted above.								
11	Unity gain, 100 kc	0 db	HP	2	100	20	1000	0.25	100 kc
	Measure the gain of the Filter from input to output. Tolerance: zero ±1 db. If gain is off tolerance, change the value of C230.								

TABLE 3. DETAILED TEST PROCEDURE (Cont)

STEP	PROCEDURE	Gain	Function	FREQUENCY SETTING				INPUT SIGNAL	
				HP Dial	HP Multiplier	LP Dial	LP Multiplier	Voltage	Frequency
12	High freq. response	0 db	HP	2	100	20	1000	0.25	100 kc - 1 mc
	A. Sweep the input frequency slowly from 100 kc to 1 mc, keeping the input voltage constant, and observe the output voltage on an ac VTVM. The output voltage should remain within ±1 db with respect to the input at all frequencies, except falling to less than -3 db at 1 mc. Trim capacitor, C311, may be adjusted, if necessary, so that the gain falls within this tolerance. If C311 has to be adjusted, recheck step 11. Then repeat step 12.								
	B. Set HP multiplier to 1000 and recheck Filter gain vs. frequency as described above. Tolerance: within ±1 db, falling to less than -3 db at 900 kc.								
13	Freq. response - Output loop	0 db	LP	2	100	2	1000	0.25	600 cps - 100 kc
	Connect oscillator signal to terminal No. 17 of PC201 through a 10 mfd capacitor. Change the oscillator frequency slowly from 600 cps to 100 kc and observe the output voltage change. Tolerance: less than ±1 db.								
14	Low freq. gain, +20 db	20 db	HP	2	.01	2	1000	0.5	600 cps
	Connect oscillator signal to Filter input. Observe voltage gain through the Filter from input to output. Tolerance: 19 to 21 db. Change the value of R123, if necessary, to bring the gain to within tolerance.								
15	High freq. gain, +20 db	20 db	HP	2	.01	2	1000	0.5	600 cps - 100 kc
	Observe voltage gain through the Filter as the frequency is increased to 100 kc. Tolerance: 19 to 21 db at any frequency up to 100 kc. Change the value of capacitor, C106, if necessary, for a flat response.								
16	Output impedance	0 db	HP	2	.01	2	1000	1.0	1000 cps
	A. Connect a 500 ohm load across the Filter output. Measure change in output voltage as the load is applied. Tolerance: less than 0.1 volt (1 db).								
	B. Change the input frequency to 100 kc, and repeat step 16A. Remove 500 ohm load.								
17	Low pass peaking	0 db	BP	6	1	6	100	5.0	30 cps
	Switch the LP multiplier to 10 and observe the output voltage change in db. Tolerance: +.3 to +1.2 db.								
18	High pass peaking	0 db	BP	6	1	6	100	5.0	120 cps
	Switch the HP multiplier to 10 and observe the output voltage change in db. Tolerance: +.3 to +1.2 db.								
19	Max. input voltage	0 db	BP	19	1	21	1000	5.0	60 cps
	Connect the Filter output to an oscilloscope, synchronized to display two or three cycles of waveform. Increase Filter input signal until point of clipping or distortion is observed on the output waveform. Adjust input level just below this point. Measure input voltage level. Tolerance: greater than 10 volts rms.								
20	Max. input voltage	20 db	BP	19	1	21	1000	0.5	60 cps
	Increase Filter input signal as in step 19 above. Measure maximum input voltage. Tolerance: greater than 1 volt rms.								
21	Leakage of input coupling capacitor	20 db	BP	19	1	21	1000	0.5	60 cps
	A. Connect oscillator to Filter input through a 1 mfd capacitor which has a leakage resistance greater than 100 megohms. Connect cathode of V10 (B plus) to the Filter input through approximately a 1 megohm resistor. Increase oscillator signal as in steps 19 and 20 above. Tolerance: maximum signal should be greater than 1 volt rms.								
	B. Repeat step 21A above, except connect B minus (terminal No. 4 of PC401) instead of B plus through the 1 megohm resistor to the Filter input. Use same tolerance of signal as in step 21A.								
	NOTE: External + and - 175 volt power supplies may be used for the above steps. Allow ample time for the capacitors to charge.								
22	Low pass Max. attenuation, BP mode	0 db	BP	2	100	2	1000	10.0	25 kc
	Measure the Filter output voltage. Tolerance: less than 1 millivolt.								
	NOTE: Filter must be in its metal cabinet or adequately shielded for steps 22, 23, and 24.								

TABLE 3. DETAILED TEST PROCEDURE (Cont)

STEP	PROCEDURE	Gain	Function	FREQUENCY SETTING				INPUT SIGNAL	
				HP Dial	HP Multiplier	LP Dial	LP Multiplier	Voltage	Frequency
23	High pass Max. attenuation, BR mode	0 db	BR	20	1000	2	.01	10	1700 cps
	Measure the Filter output voltage. Tolerance: less than 1 millivolt.								
24	High pass Max. attenuation, BP mode	0 db	BP	20	1000	20	1000	10	1700 cps
	Measure the Filter output voltage. Tolerance: less than 1 millivolt.								
25	Gain change vs HP Tuning	0 db	BP	19-1.9	10	21	1000	5.0	2000 cps
	Rotate HP dial slowly from 19 to 1.9, and observe any changes in output voltage. Tolerance: zero ±1 db.								
26	Gain change vs Function Switch	0 db	HP	1.9	10	21	1000	5	2000 cps
	Observe change in output voltage as the Function is switched from BP to HP. Tolerance: less than ±1 db.								
27	Gain change vs HP band-switching	0 db	HP	1.9	.01	21	1000	2.5	100 kc
	Observe change in output voltage while switching HP frequency multiplier, successively, to all six positions. Tolerance: less than ±1 db.								
28	Maximum dc signal	0 db	LP	1.9	.01	21	1000	--	dc
A.	Connect an adjustable 20 volt battery or dc power supply to the Filter input. Connect a dc scope on the Filter output. Increase the input voltage until the output dc signal clamps. Measure the input voltage. Tolerance: at least 15 volts.								
B.	Switch gain to 20 db and repeat. Tolerance: at least 1.5 volts.								
29	Scope phase shift check	--	--	--	--	--	--	5	20,000 cps
	Connect scope horizontal input to oscillator output, and adjust scope for a sweep 4 cm wide. Remove scope horizontal input. Connect scope vertical input to oscillator output, and adjust scope for a line 4 cm high. Connect both horizontal and vertical inputs to oscillator and check for equal horizontal and vertical phase shift in scope amplifier by noting a completely closed ellipse (straight line) at about a 45-degree angle.								
30	Check phase calibration of HP dial at 6 cps	0 db	HP	6	1	20	1000	5	6 cps
	Connect scope vertical input to cathode of V4B (terminal No. 9 on PC201) and horizontal input to terminal No. 8 of PC101A. Adjust HP dial to close the ellipse at about a 135 degree angle. Tolerance is a dial setting of from 5.7 to 6.3. If out of tolerance, loosen set-screws and reset dial.								
31	3 db attenuation calibration of HP dial at 6 cps	0 db	HP	6	1	20	1000	5	6 cps
	Switch HP multiplier to .1 and adjust the oscillator for a reading of exactly 5 volts (20 divisions on scope). Switch HP multiplier back to 1, and adjust HP dial until the scope reads -3 db from previous reading (14 divisions). Tolerance is a dial setting of from 5.7 to 6.3 If out of tolerance, refer to Section 5.3, and repeat step 30.								
32	Check phase calibration of HP dial at 2 cps	0 db	HP	2	1	20	1000	5	2 cps
	Proceed as in step 30, assuming that scope phase shift has not changed. Tolerance is a dial setting of from 1.9 to 2.1. If out of tolerance, proceed as described in step 33.								
33	3 db attenuation calibration of HP dial at 2 cps	0 db	HP	2	1	20	1000	5	2 cps
	Proceed as in step 31, switching HP frequency multiplier to .1 position to set scope and returning to 1 for final reading. Tolerance is a dial setting of from 1.9 to 2.1. If out of tolerance, refer to Section 5.4 and repeat step 32.								
34	Check phase calibration of HP dial at 20 cps	0 db	HP	20	1	20	1000	5	20 cps
	Proceed as in step 30, assuming that scope phase shift has not changed. Tolerance is a dial setting of from 19 to 21. If out of tolerance, proceed as described in step 35.								

TABLE 3. DETAILED TEST PROCEDURE (Cont)

STEP	PROCEDURE	Gain	Function	FREQUENCY SETTING				INPUT SIGNAL	
				HP Dial	HP Multiplier	LP Dial	LP Multiplier	Voltage	Frequency
35	3 db attenuation calibration of HP dial at 20 cps	0 db	HP	20	1	20	1000	5	20 cps
	Proceed as in step 31, switching HP frequency multiplier to .1 position to set scope and returning to 1 for final reading. Tolerance is a dial setting of from 19 to 21. If out of tolerance, refer to Section 5.4 and repeat step 34. NOTE: For this step and subsequent steps pertaining to 3 db attenuation calibration at frequencies greater than 10 cps, an ac VTVM may be easier to use than the scope.								
36	3 db attenuation calibration of HP dial at 6 on the dial for all bands	0 db	HP	6	--	20	1000	5	--
	Follow procedure in step 31 for all six positions of HP multiplier switch. On each of these bands, adjust scope with multiplier switch in next lower position; then, restore multiplier switch so that HP frequency is equal to oscillator frequency, and adjust HP dial for a vertical deflection of 14 divisions. For first position (.01) of HP multiplier switch, it will be necessary to adjust scope at an oscillator frequency of .6 cps with HP frequency multiplier on .01, and then reduce oscillator frequency to .06 cps. Oscillator output voltage should be checked with scope to make certain that amplitude does not change at .06 cps. Adjust HP dial for a vertical deflection of 14 divisions. Tolerance (all bands) is a dial setting of from 5.7 to 6.3. If out of tolerance on band 6 (1000), adjust C201. If out of tolerance on other bands, check the capacitors associated with the bands in question.								
37	3 db attenuation calibration of HP dial at 2 and 20 on bands 5 and 6.	0 db	HP	--	--	20	1000	5	--
	Follow procedure in step 31 for 2 and 20 on the dial on bands 5 (100) and 6 (1000). Tolerance: dial reading should be within ± 5% of frequency checked. If out of tolerance on band 6 (1000), adjust trim capacitor C263. After adjusting C263, recheck calibration at 2, 6, and 20.								
38	Check phase calibration of LP dial at 6 cps	0 db	LP	2	.01	6	1	5	6 cps
	Connect horizontal input to terminal No. 10 on PC101A and vertical input to Filter OUTPUT. Adjust LP dial to close ellipse at about 135 degrees. Tolerance is a dial setting of from 5.7 to 6.3. If out of tolerance, loosen set-screws and reset dial.								
39	3 db attenuation calibration of LP dial at 6 cps	0 db	LP	2	.01	6	1	5	6 cps
	Switch LP frequency multiplier to 10 position, and adjust oscillator output for a scope vertical deflection of exactly 20 divisions (5 volts). Return LP frequency multiplier to 1 position. Adjust LP dial for a scope vertical deflection of 14 divisions (minus 3 db). Tolerance is a dial setting of from 5.7 to 6.3. If out of tolerance, change value of R324 and repeat step 38.								
40	Check phase calibration of LP dial at 2 cps	0 db	LP	2	.01	2	1	5	2 cps
	Proceed as in step 38, assuming that scope phase shift has not changed. Tolerance is a dial setting of from 1.9 to 2.1. If out of tolerance, proceed as described in step 41.								
41	3 db attenuation calibration of LP dial at 2 cps	0 db	LP	2	.01	2	1	5	2 cps
	Proceed as in step 39, switching LP frequency multiplier to 10 position to set scope and returning to 1 position for final reading. Tolerance is a dial setting of from 1.9 to 2.1. If out of tolerance, refer to Section 5.4 and repeat step 40.								
42	Check phase calibration of LP dial at 20 cps	0 db	LP	2	.01	20	1	5	20 cps
	Proceed as in step 38, assuming that scope phase shift has not changed. Tolerance is a dial setting of from 19 to 21. If out of tolerance, proceed as described in step 43.								
43	3 db attenuation calibration of LP dial at 20 cps	0 db	LP	2	.01	20	1	5	20 cps
	Proceed as in step 39, switching LP frequency multiplier to 10 position to set the scope and returning to 1 position for final reading. Tolerance is a dial setting of from 19 to 21. If out of tolerance refer to Section 5.4 and repeat step 42.								

TABLE 3. DETAILED TEST PROCEDURE(Cont)

STEP	PROCEDURE	GAIN	Function	FREQUENCY SETTING				INPUT SIGNAL	
				HP Dial	HP Multiplier	LP Dial	LP Multiplier	Voltage	Frequency
44	3 db attenuation calibration of LP dial at 6 on dial for all bands	0 db	LP	2	.01	6	--	5	--
	Follow procedure of step 39 for all six positions of LP multiplier switch. On each of these bands adjust scope with multiplier switch in next higher position; then, restore multiplier switch so that LP frequency is equal to oscillator frequency, and adjust LP dial for a vertical deflection of 14 divisions. For last position (1000) of LP multiplier switch, it will be necessary to adjust scope at an oscillator frequency of 600 cps with LP frequency multiplier on 1000 and then increase oscillator frequency to 6 kc. Oscillator output voltage should be checked with scope to make certain that amplitude does not change at 6 kc. Adjust LP dial for a vertical deflection of 14 divisions (-3 db). Tolerance (all bands) is a dial setting of from 5.7 to 6.3. If out of tolerance on band 6 (1000), adjust C253. If out of tolerance on other bands, check the capacitors associated with the bands in question.								
45	3 db attenuation calibration of LP dial at 2 and 20 on bands 5 and 6	0 db	LP	2	.01	--	--	5	--
	Follow procedure of step 39 for 2 and 20 on the dial on bands 5 (100) and 6 (1000). Tolerance: dial reading should be within ± 5% of frequency checked. If 20 kc is out of tolerance, adjust C238 and recheck 6 kc calibration.								
46	Calibration of LP dial for peaking factor	0 db	LP	5	1000	20	1000	5	10 kc
A.	Remove scope horizontal input from terminal No. 10 of PC101. Connect ac VTVM across Filter output and adjust the input signal for a reading of 14 db on the VTVM. Change oscillator frequency to 20 kc and adjust the LP dial for a reading of 9.75 db on the ac VTVM. Dial reading should be within 19 to 21. If out of tolerance, adjust C245 and repeat 6 kc and 20 kc calibration, as described in steps 44 and 45.								
B.	Repeat part A above for the peaking at 2 kc, using 1 kc input frequency as the reference point.								
47	Null at 1 kc	0 db	BR	20	100	5	100	5	1 kc
	Adjust both dials to minimize the signal. Output signal should be less than 5 millivolts. This will, of course, depend on the distortion of the oscillator used to supply the input signal. The 5 millivolts applies only when input signals with less than .1% distortion are used.								
48	2 kc gain at null	0 db	BR	null setting	100	null setting	100	5	2 kc
	Measure output signal. Tolerance: between 1.75 and 5 volts.								
49	500 cps gain at null	0 db	BR	null setting	100	null setting	100	5	500 cps
	Measure output signal. Tolerance: between 1.75 and 5 volts.								
50	Null at 10 kc	0 db	BR	20	1000	5	1000	5	10 kc
	Adjust both dials to minimize the signal. Signal should be less than 5 millivolts. (Same note applies as in step 47.)								
51	20 kc gain at null	0 db	BR	null setting	1000	null setting	1000	5	20 kc
	Measure output signal. Tolerance: between 1.75 and 5 volts.								
52	5 kc gain at null	0 db	BR	null setting	1000	null setting	1000	5	5 kc
	Measure output signal. Tolerance: between 1.75 and 5 volts.								
53	Maximum input, 1 mc	0 db	HP	20	1000	--	--	.5	1 mc
	Increase input signal to point where output appears to overload or distort. Measure the input signal just below this point. Tolerance: at least 0.5 volts rms.								
54	Output hum and noise	0 db	BP	3	10	12	10	Short	--
A.	Short the Filter input. Install Filter in cabinet or make sure that bottom is adequately shielded. Using shielded meter cables, check hum and noise on output. Tolerance: less than 1 mv.								
B.	Repeat step A with gain switch in 20 db position. Tolerance: less than 1 mv.								

CAUTION

Paragraphs 5.3 and 5.4 that follow are not part of the normal calibration and adjustment procedures. They should not be used except when referenced in the frequency dial calibration sections of the Detailed Test Procedure

5.3 ALIGNMENT OF DIAL TUNING POTENTIOMETER ASSEMBLIES

Figure 16A shows the rear view of the LP (low-pass) dial tuning potentiometer assembly, and Figure 16B shows the rear view of the HP (high-pass) dial tuning potentiometer assembly.

a. Set HIGH-PASS frequency dial (left-hand dial) to 6.

b. Connect a bridge between points A1-A2 (see Figure 16B) on the terminal board. The bridge should read 247K ohms ± 5% (resistance of potentiometer P201A).

c. Repeat step b for points B1-B2, C1-C2, and D1-D2 (see Figure 16B). The resistance measurements should be within ± 5% of those readings in Table 4.

d. If the resistance limits of steps b and c cannot be obtained, adjust the HIGH-PASS dial to see if all measurements fall within the limits of Table 4 at one setting. If they do, loosen the dial, slip dial to 6, and tighten. If all the resistances do not fall within limits at one setting, loosen the gear on the potentiometer that is off, and readjust until it falls within limits.

e. Set LOW-PASS dial (right-hand dial) to 6.

f. Repeat steps b through c, but refer to Figure 16A. Slip dial or adjust individual potentiometer as described in step d as necessary to meet the limits of Table 4.

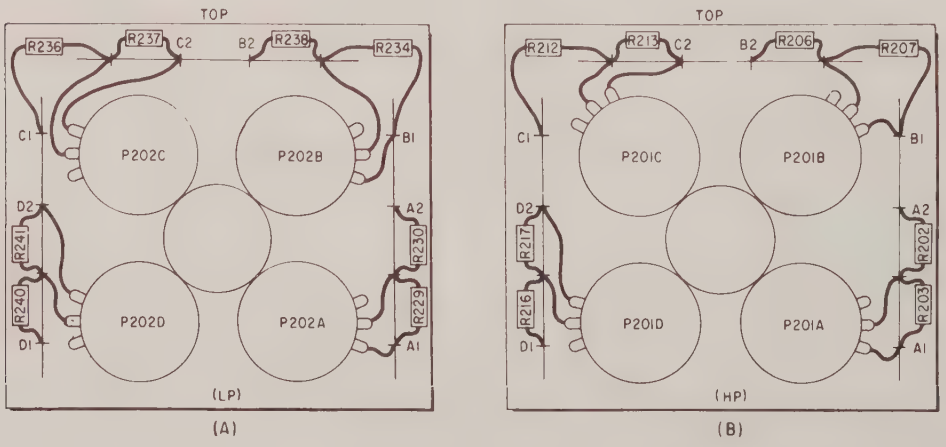

Figure 16. Rear View of Dial Tuning Potentiometer Assemblies

TABLE 4

LP AND HP POTENTIOMETER
RESISTANCE MEASUREMENTS

LP Pot. Resistances*		HP Pot. Resistances*	
Connect bridge across	Should read (ohms ±5%)	Connect bridge across	Should read (ohms ±5%)
A1-A2	233K	A1-A2	247K
B1-B2	230K	B1-B2	265K
C1-C2	265K	C1-C2	250K
D1-D2	241K	D1-D2	265K

*All resistance values given include the fixed trimming resistor associated with each potentiometer. All resistance values should be measured on a bridge capable of reading to at least 1% accuracy.

5.4 ADJUSTMENT OF TRIM RESISTANCE OF TUNING POTENTIOMETERS

When the high and low ends of the LOW-PASS and HIGH-PASS dials do not calibrate with respect to the center-of-dial (6) position during the Detailed Test Procedures described in Table 3, refer to Table 5 for adjustment of trim resistances for the appropriate tuning potentiometers.

TABLE 5

TRIM RESISTOR ADJUSTMENT FOR TUNING POTENTIOMETERS
(FUNCTION SWITCH ON BAND-PASS)

Condition when Filter dial is adjusted for 180° phase shift*		Increase or decrease trim resistance as idnicated below							
		HP potentiometers				LP potentiometers			
		Low end of dial		High end of dial		Low end of dial		High end of dial	
Dial Reading	Output Amplitude	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase
OK	LOW	R203	R207	R202	R206	R234	R229	R233	R230
		R213	R217	R212	R216	R241	R237	R246	R236
OK	HIGH	R207	R203	R206	R202	R229	R234	R230	R233
		R217	R213	R216	R212	R237	R241	R236	R240
LOW	LOW		R207, R217		R206, R216		R229, R237		R230, R236
HIGH	LOW	R203, R213		R202, R212		R234, R241		R233, R240	
LOW	HIGH		R203, R213		R202, R216		R234, R241		R233, R240
HIGH	HIGH	R207, R217		R206, R216		R229, R237		R230, R236	
LOW	OK		R203, R207 or R213, R217		R202, R206 or R212, R216		R229, R234 or R237, R241		R230, R236 or R236, R240
HIGH	OK	R203, R207 or R213, R217		R202, R206 or R212, R216		R229, R234 or R237, R241		R230, R233 or R236, R240	

* This is described in detail in the calibration of the HIGH-PASS and LOW-PASS dials of the Detailed Test Procedure (see Table 3). The dial should agree with the input frequency when the phase shift is 180°, and the Filter output amplitude should be attenuated minus 3 db from the normal pass band gain when the phase shift is 180°.

SECTION 6

PARTS LIST

6.1 INTRODUCTION

The Manufacturer's Code and Part No. columns give the manufacturer and his part number for each component. The manufacturers' part numbers listed may differ from the part numbers of some components found in the instrument. These substitutions, however, are direct replacements.

The Description column contains a detailed description of each part. If a part is used in the instrument more than once, the description is not repeated but is indicated by the term "Same as".

The Quantity column lists the total quantity of parts used in an instrument, and is given only in the first listing.

MANUFACTURERS CODE

CODE	NAME	ADDRESS
A-B	Allen-Bradley Company	Milwaukee, Wisconsin
AER	Aerovox Corporation	New Bedford, Mass.
ARCO	Arco Electronics, Inc.	New York, New York
BU	Bussman Mfg. Co.	St. Louis, Missouri
C-D	Cornell-Dubilier Elec. Co.	South Plainfield, N. J.
C-H	Cutler-Hammer, Inc.	Milwaukee, Wisconsin
EL	Elmenco Co.	Willimantic, Conn.
GE	General Electric Co.	Schenectady, New York
K-H	Krohn-Hite Corporation	Cambridge, Mass.
MOT	Motorola Semiconductor Products, Inc.	Phoenix, Arizona
NAT	National Radio Co.	Melrose, Mass.
RCA	Radio Corp. of America	Somerville, N. J.
R-I	Resistors, Inc.	Chicago, Illinois
SP	Sprague Electric Co.	North Adams, Mass.
TEL	Telefunken Co. (c/o American Elite, Inc.)	Long Island City, N. Y.
TRAN	Transitron Electronics Corp.	Wakefield, Mass.
UM	United Mineral & Chemical Corp.	New York, New York
UN	Unitrode Corporation	Watertown, Mass.
W-L	Ward-Leonard Elec. Co.	Chicago, Illinois

6.2 ORDERING PARTS

When ordering parts from Krohn-Hite Corporation, the following information should be supplied: 1) Model No. of the instrument; 2) Serial No. of the instrument; 3) Description; 4) Manufacturer; 5) Part No.

6.3 PARTS LIST FOR MODEL 335(R)

SCHEMATIC SYMBOL	DESCRIPTION	QTY	MFG. CODE	MFG. PART NO.
	CAPACITORS			
C101	470 MMF, 10%, 500V, Mica	2	EL	DM19C471K
C102	0.039 MF, 10%, 400V, Paper WFG	2	C-D	WMF-4S39G
C103	220 MMF, 10%, 500V, Mica	2	EL	DM15C221K
C104	15 MMF, 10%, 500V, Mica	1	EL	DM15C150K
C105	56 MMF, 10%, 500V, Mica	1	EL	DM15C560K
C106	110 MMF, 5%, 500V, Mica, (TRIM)	1	EL	DM15C111J
C107	0.022 MF, 10%, 400V, Paper WFG	6	C-D	WMF-4S22G
C108	20 MF, +75%-10%, 100V, Electrolytic, WPS	2	SP	30D210A1
C109	Same as C107			
C110	7 to 100 MMF Variable Capacitor	2	ARCO	423
C111	75 MMF, 10%, 500V, Mica, (TRIM)	2	EL	DM15C750K
C112	680 MMF, 10%, 500V, Mica	1	EL	DM19C681K
C201	1.5 to 20 MMF Variable Capacitor	3	ARCO	T50210 Type 402
C202	47 MMF, 5%, 500V, Mica	2	EL	CM19C470J
*C203	0.001 MF, 1%, 100V, Mylar	8	K-H	BCM-102
*C204	0.01 MF, 1%, 100V, Mylar	8	K-H	BCM-101
*C205	0.1 MF, 1%, 100V, Mylar	8	K-H	BCM-100
*C206	1 MF, 1%, 200V, Mylar	8	K-H	BCM-108
*C207	10 MF, 1%, 75V, Metalized-paper	8	K-H	MFT-104
C208	110 MMF, 1%, 500V, Mica	1	EL	CM19C111F
C209	Same as C203			
C210	Same as C204			
C211	Same as C205			
C212	Same as C206			
C213	Same as C207			
C214	49 MMF, 1%, 500V, Mica	2	EL	CM19C490F
C215	Same as C203			
C216	Same as C204			

* These capacitors have a basic tolerance of 5%; they are selected and trimmed at the factory for correct calibration.

WFG = Fibreglass wrapped
WPS = With plastic sleeve

SCHEMATIC SYMBOL	DESCRIPTION	QTY	MFG. CODE	MFG PART NO.
C217	Same as C205			
C218	Same as C206			
C219	Same as C207			
C220	133 MMF, 1%, 500V, Mica	1	EL	CM19C133F
C221	Same as C203			
C222	Same as C204			
C223	Same as C205			
C224	Same as C206			
C225	Same as C207			
C226	1 MF, 10%, 400V, Paper, WFG	4	C-D	MMW-4W1
C227	0.1 MF, 10%, 400V, Paper, WFG	3	C-D	WMF-4P1
C228	1000 MMF, 10%, 500V, Mica	2	EL	DM19C102K
C229	200 MMF, 10%, 500V, Mica	1	EL	DM15C201K
C230	82 MMF, 10%, 500V, Mica, (TRIM)	1	EL	DM15C820K
C231	Same as C226			
C232	130 MMF, 1%, 500V, Mica	1	EL	CM19131F
C233	Same as C203			
C234	Same as C204			
C235	Same as C205			
C236	Same as C206			
C237	Same as C207			
C238	14 to 150 MMF Variable Capacitor	2	ARCO	T51410 Type 424
C239	Same as C214			
C240	Same as C203			
C241	Same as C204			
C242	Same as C205			
C243	Same as C206			
C244	Same as C207			
C245	Same as C201			
C246	115 MMF, 5%, 500V, Mica	1	EL	CM19C115J
C247	Same as C203			
C248	Same as C204			
C249	Same as C205			
C250	Same as C206			
C251	Same as C207			
C252	270 MMF, 10%, 500V, Mica	1	EL	DM15C271K
C253	Same as C201			
C254	Same as C202			
C255	Same as C203			
C256	Same as C204			
C257	Same as C205			
C258	Same as C206			
C259	Same as C207			

WFG = Fiberglass wrapped
WPS = With plastic sleeve

SCHEMATIC SYMBOL	DESCRIPTION	QTY	MFG. CODE	MFG. PART NO.
C260	Same as C228			
C261	Same as C107			
C262	150 MMF, 10%, 500V, Mica	1	EL	CM19C151K
C263	Same as C238			
C264	50 MF, +75%-10%, 3V, Electrolytic, WPS	1	SP	30D506G003BB4
C301	2000 MMF, 10%, 500V, Mica	1	EL	DM19C202K
C302	Same as C107			
C303	Same as C111			
C304	Same as C102			
C305	Same as C103			
C306	33 MMF, 5%, 500V, Mica	1	EL	D15C330J
C307	Same as C107			
C308	40 MF, 350V, Electrolytic	1	SP	TVA-1611
C309	Same as C108			
C310	Same as C107			
C311	Same as C110			
C312	100 MMF, 10%, 500V, Mica	1	EL	DM15C101K
C313	0.0022 MF, 10%, 400V, Paper, WFG	1	C-D	WMF-4D22
C314	Same as C226			
C315	Same as C226			
C401	4 MF, 20%, 330V, AC, Oil	2	AER	P104J
C402	Same as C401			
C403	0.01 MF, 20%, 500V, Ceramic	1	SP	29C214A
C404	Same as C227			
C405	0.001 MF, 20%, 500V, Ceramic	6	SP	40C230A
C406	Same as C227			
C407	40 MF, +100%-10%, 450V, Electrolytic, Can	2	SP	D17665-6343
C408	Same as C407			
C409	Same as C405			
C410	Same as C405			
C411	Same as C405			
C412	Same as C405			
C413	Same as C101			
C414	Same as C405			
C415	2000 MF, +100%-10%, 50V, Electrolytic, Can	1	SP	D38509-6343
C416	4 MF, +75%-10%, 50V, Electrolytic	1	SP	30D192A1

WFG = Fiberglass wrapped
WPS = With plastic sleeve

SCHEMATIC SYMBOL	DESCRIPTION	QTY	MFG. CODE	MFG. PART NO.
	RESISTORS			
R101	22M, 1/2W, 10%, Carbon	2	A-B	EB-2261
R102	100 ohm, 1/2W, 20%, Carbon	8	A-B	EB-1012
R103	680 ohm, 1/2W, 10%, Carbon	1	A-B	EB-6811
R104	47K, 1/2W, 5%, Deposited-carbon	3	UM	LCA-0.33
R105	3.3K, 1/2W, 10%, Carbon	1	A-B	EB-3321
R106	36K, 1W, 5%, Deposited-carbon	1	UM	SCD1
R107	1K, 1/2W, 5%, Deposited-carbon	1	UM	LCA-0.33
R108	Same as R102			
R109	4.7M, 1/2W, 5%, Deposited-carbon	4	UM	LCA-0.33
R110	10K, 1/2W, 10%, Carbon	1	A-B	EB-1031
R111	Same as R109 (TRIM)			
R112	1.8M, 1/2W, 5%, Deposited-carbon, (TRIM)	2	UM	LCA-0.33
R113	3.6M, 1/2W, 5%, Deposited-carbon, (TRIM)	2	UM	LCA-0.33
R114	Same as R102			
R115	47K, 1W, 10%, Carbon	2	A-B	GB-4731
R116	220 ohm, 1/2W, 10%, Carbon	3	A-B	EB-2211
R117	1K, 1/2W, 10%, Carbon	2	A-B	EB-1021
R118	220K, 1/2W, 5%, Carbon	2	A-B	EB-2245
R119	2.2M, 1/2W, 5%, Carbon	2	A-B	EB-2255
R120	Same as R102			
R121	27K, 1/2W, 5%, Deposited-carbon	1	UM	LCA-0.33
R122	16K, 1/2W, 5%, Deposited-carbon	1	UM	LCA-0.33
R123	1.8K, 1/2W, 5%, Deposited-carbon, (TRIM)	1	UM	LCA-0.33
R124	22K, 5W, 5%, Wire-wound	2	R-I	5W Axial
R125	40 ohm, 3W, 5%, Wire-wound	2	R-I	3W Axial
R201	3.9K, 1/2W, 10%, Carbon	4	A-B	EB-3921
R202	TRIM, 1/2W, Carbon		A-B	
R203	TRIM, 1/2W, Carbon		A-B	
R204	100K, 1/2W, 10%, Carbon	5	A-B	EB-1041
R205	Same as R201			
R206	TRIM, 1/2W, Carbon		A-B	
R207	TRIM, 1/2W, Carbon		A-B	
R208	22K, 1/2W, 5%, Carbon	2	A-B	EB-2235
R209	Same as R204			
R210	Same as R201			
R211	470 ohm, 1/2W, 10%, Carbon	3	A-B	EB-4711
R212	TRIM, 1/2W, Carbon		A-B	

SCHEMATIC SYMBOL	DESCRIPTION	QTY	MFG. CODE	MFG. PART NO.
R213	TRIM, 1/2W, Carbon		A-B	
R214	Same as R204			
R215	Same as R201			
R216	TRIM, 1/2W, Carbon		A-B	
R217	TRIM, 1/2W, Carbon		A-B	
R218	18K, 1/2W, 5%, Carbon	1	A-B	EB-1835
R219	100K, 1/2W, 5%, Carbon	3	A-B	EB-1045
R220	Same as R219 (TRIM)			
R221	47K, 1/2W, 5%, Carbon	1	A-B	EB-4735
R222	TRIM, 1/2W, Carbon		A-B	
R223	33K, 1/2W, 5%, Carbon	1	A-B	EB-3335
R224	Same as R208			
R225	TRIM, 1/2W, Carbon		A-B	
R226	Same as R219			
R227	240K, 1/2W, 5%, Carbon, (TRIM)	1	A-B	EB-2445
R228	390K, 1/2W, 5%, Carbon	1	A-B	EB-3945
R229	TRIM, 1/2W, Carbon		A-B	
R230	TRIM, 1/2W, Carbon		A-B	
R231	43K, 1/2W, 5%, Carbon	1	A-B	EB-4335
R232	180K, 1/2W, 5%, Carbon	1	A-B	EB-1845
R233	TRIM, 1/2W, Carbon		A-B	
R234	TRIM, 1/2W, Carbon		A-B	
R235	Same as R204			
R236	TRIM, 1/2W, Carbon		A-B	
R237	TRIM, 1/2W, Carbon		A-B	
R238	27K, 1/2W, 5%, Carbon	4	A-B	EB-2735
R239	Same as R118			
R240	TRIM, 1/2W, Carbon		A-B	
R241	TRIM, 1/2W, Carbon		A-B	
R242	56K, 1W, 10%, Carbon	1	A-B	GB-5631
R243	Same as R238			
R244	1.5M, 1/2W, 10%, Carbon	1	A-B	EB-1551
R245	120K, 1/2W, 5%, Carbon	1	A-B	EB-1245
R246	82K, 1/2W, 5%, Carbon	1	A-B	EB-8235
R247	Same as R238			
R248	Same as R238			
R301	Same as R101			
R302	Same as R102			
R303	330 ohm, 1/2W, 10%, Carbon	1	A-B	EB-3311
R304	Same as R104			
R305	620 ohm, 1/2W, 5%, Carbon	1	A-B	EB-6215
R306	Same as R104			
R307	47K, 1W, 5%, Deposited-carbon	1	UM	SCD1
R308	Same as R102			
R309	Same as R109			
R310	220K, 1/2W, 10%, Carbon	6	A-B	EB-2241
R311	Same as R109			

SCHEMATIC SYMBOL	DESCRIPTION	QTY	MFG. CODE	MFG. PART NO.
R312	Same as R112			
R313	Same as R102			
R314	Same as R113			
R315	Same as R115			
R316	Same as R116			
R317	Same as R117			
R318	Same as R310			
R319	Same as R119			
R320	Same as R102			
R321	18K, 1/2W, 5%, Deposited-carbon	2	UM	LCA-0.33
R322	10K, 1/2W, 5%, Deposited-carbon	1	UM	LCA-0.33
R323	2.7K, 1/2W, 5%, Deposited-carbon	1	UM	LCA-0.33
R324	Same as R321			
R325	4.7K, 1/2W, 5%, Carbon	1	A-B	EB-4725
R326	Same as R124			
R327	62 ohm, 1/2W, 5%, Carbon	1	A-B	EB-6205
R328	Same as R125			
R401	Same as R211			
R402	4.7K, 1/2W, 10%, Carbon	2	A-B	EB-4721
R403	27K, 2W, 10%, Carbon	1	A-B	HB-2731
R404	470K, 1/2W, 10%, Carbon	1	A-B	EB-4741
R405	Same as R310			
R406	1.2M, 1/2W, 10%, Carbon	3	A-B	EB-1251
R407	1.8M, 1/2W, 10%, Carbon	2	A-B	EB-1851
R408	12K, 1W, 10%, Carbon	1	A-B	GB-1231
R409	560K, 1/2W, 5%, Carbon (TRIM)	2	A-B	EB-5645
R410	Same as R409 (TRIM)			
R411	510K, 1/2W, 5%, Carbon	3	A-B	EB-5145
R412	Same as R411			
R413	Same as R406			
R414	Same as R310			
R415	Same as R310			
R416	Same as R411			
R417	1.2M, 1/2W, 5%, Carbon	1	A-B	EB-1255
R418	1.8M, 1/2W, 5%, Carbon	1	A-B	EB-1855
R419	Same as R310			
R420	Same as R204			
R421	22K, 1/2W, 10%, Carbon	1	A-B	EB-2231
R422	Same as R406			
R423	Same as R407			
R424	Same as R211			
R425	2K, 1/2W, 5%, Carbon	1	A-B	EB-2025
R426	160K, 1/2W, 5%, Carbon, (TRIM)	1	A-B	EB-1645

SCHEMATIC SYMBOL	DESCRIPTION	QTY	MFG. CODE	MFG. PART NO.
R427	15K, 5W, 5%, Wire-wound	1	R-I	5W Axial
R428	15 ohm, 20W, 10%, Wire-wound	1	W-L	20S15
R429	4K, 20W, 5%, Wire-wound	1	W-L	20W Ministrip
R430	Same as R116			
R431	0.1 ohm, 3W, 10%, Wire-wound	1	R-I	3W Axial
R432	Same as R402			
	OTHER COMPONENTS			
CR201	Diode, Type IN456	2	TRAN	IN456
CR401	Part of rectifier assembly (MOT Part No. MD952-2)			
CR402	Same as CR401			
CR403	Same as CR401			
CR404	Same as CR401			
CR405	Same as CR201			
F401	Fuse, 1 1/2A, Slo-blo		BU	MDL-1 1/2
F402	Fuse, 3/4A, Slo-blo		BU	MDL-3/4
F403	Fuse, 1 1/2A, Fast-blo	1	BU	AGC-1 1/2
I401	Lamp	2	GE	1829
I402	Same as I401			
L101	Choke, RF, 1 Millihenry	4	NAT	R-50-1
L301	Same as L101			
L302	Same as L101			
L303	Choke, 100 Microhenry	1	NAT	R-1500-37
L304	Same as L101			
L401	Choke, 7 Henry at 55MA	1	K-H	C-100-7
P101	Potentiometer, 100K, 2W, Carbon	2	A-B	JAIL040S104UC
P102	Potentiometer, 250K, 2W, Carbon	2	A-B	JAIL040S254UC
P201A, B, C, D	Potentiometer, Part of tuning pot. assembly (K-H Part No. 335-HP-201)			
P202A, B, C, D,	Potentiometer, Part of tuning pot. assembly (K-H Part No. 335-LP-202)			
P203	Potentiometer, 1M, 2W, Carbon	1	A-B	JAIL040S15MC
P301	Same as P101			
P302	Same as P102			
Q401	Transistor, PNP, Germanium	1	MOT	SP164
Q402	Transistor, PNP, Germanium	1	RCA	2N1183

SCHEMATIC SYMBOL	DESCRIPTION	QTY	MFG. CODE	MFG. PART NO.
S101	Switch, Rotary	1	K-H	335-101
S201	Switch, Rotary	1	K-H	335-201
S202	Switch, Rotary	1	K-H	335-202
S203	Switch, Rotary	1	K-H	335-203
S401	Switch, Toggle	1	C-H	8280-K16
T401	Transformer, Power	1	K-H	P-100-45D
V1	Tube, Type 12AY7	2	RCA	12AY7
V2	Tube, Type 6GH8A	2	RCA	6GH8A
V3	Tube, Type 12AX7A	6	RCA	12AX7A
V4	Same as V3			
V5	Same as V3			
V6	Tube, Type 12AT7	1	RCA	12AT7
V7	Same as V1			
V8	Same as V2			
V9	Tube, Type 6AX5GT	1	RCA	6AX5GT
V10	Tube, Type 6AU5GT	1	RCA	6AU5GT
V11	Tube, Type 0G3	1	TEL	0G3
V12	Same as V3			
V13	Tube, Type 12AU7A	1	RCA	12AU7A
V14	Same as V3			
V15	Same as V3			
Z101	Diode, Zener, Nominal 82 volts	2	UN	UZ782
Z301	Same as Z101			

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MODEL 335(R)

THE FOLLOWING CHANGES AND CORRECTIONS ARE NOT REFLECTED ON THE SCHEMATICS (Power Supply dated REV. 9/8/65 and Main Amplifier dated REV. 8/3/65) AND MAY BE ADDED AT THE DISCRETION OF THE CUSTOMER.

STARTING WITH SERIAL NUMBER	CHANGES AND CORRECTIONS
318	Change R112 & R312 (1.15M,1/2W,1%,MF) to 1.13M,1/2W,1%,MF. Add a 100K,1W resistor across P101.
319	Change R310 (220K,10%,1/2W) to 110K,10%,1/2W.
282	On the schematic: R236 TRIM is shown in the wrong position. It should be shown located between the junction of R237 & the CA of P202C and the junction of pin 3 of V5B and CA of S202A. It is in series with these two junctions.
322	1) Label C101 as "TRIM". 2) Change C229 (200 mmf,10%,500V) to 300 mmf,500V,TRIM. 3) Change C230 (82 mmf,10%,500V) to 110 mmf,500V,TRIM. 4) Delete (a) R325 (4.7K,5%,1/2W) (b) C313 (.0022 mf,10%,400V) (c) C252 (270 mmf,10%,500V). 5) Add C264 (TRIM) in series with R249 (TRIM) and add these series components in parallel with R239 (with R249 connected to B-). 6) Replace R236 with a jumper and place R236 between the junction R237 & P202C and pin 7 of V6. 7) Replace R240 with a jumper and place R240 between the junction R241 & P202D and pin 2 of V6. 8) Change C254 (47 mmf,5%,500V) to 10 mmf,5%,500V.
369	Change R247 & R248 (27K,5%,1/2W) to 10K,10%,1/2W.
369	Add a contact at location 4 on wafer 4B of FUNCTION switch S203. Add a capacitor (TRIM) from this contact to the junction of C229
369	Add R220A (510K,5%,1/2W) inparallel with R220 (TRIM). Change C106 (130 uuf,10%,TRIM) to 75 uuf,5%,500V).
415 (inc. 411)	Add R436 (47 ohm 1/2W) in series with the base of Q
419	Change C415 from 2000 mfd 50V to 2000 mfd. 60V.

All voltage and resistance values should be measured from pins of each socket to chassis ground with a VTVM having an input resistance of no less than 10 megohms. Voltages measured with instrument operating from 115 volts 60 cps line. Resistance measured with power line cord disconnected.

All measurements made with FUNCTION switch in BAND PASS position; GAIN switch in 0 DB position; CUTOFF FREQUENCY dials set at 10 and MULTIPLIER switches set at X10. Ground link must be in place on front or rear OUTPUT terminals of chassis.

All resistance values are in ohms, K = 1,000 ohms, M = 1,000,000 ohms. Variations of up to ±20% on all readings may be expected.

TUBE No. & Type		PIN NUMBER								
		1	2	3	4	5	6	7	8	9
V1	V	125	0±1	2±1	6	6	175	0±1	2±1	12
12AY7	R	65K	22M	50K	2.1	2.1	21K	180K	50K	3.6
V2	V	175	-94	-1	6	0	15	-92	0±1	-3.5
6GH8A	R	21K	1.3M	1K	2.1	0	64K	8K*	17K	250K
V3	V	175	0	1±1	12	0	175	-32	-30	--
12AX7A	R	21K	150K	120K	7.5	0	21K	235K	110K	--
V4	V	175	0	1±1	24	12	175	-27	-26	--
12AX7A	R	21K	150K	115K	3.4	7.5	21K	235K	105K	--
V5	V	175	-32	-31	12	24	175	1±1	2±1	--
12AX7A	R	21K	300K	110K	7.4	3.5	21K	265K	220K	--
V6	V	175	-44	-40	0	12	175	-32	-28	--
12AT7	R	21K	340K	38K	0	7	21K	255K	250K	--
V7	V	125	0±1	2±1	18	18	130	0±1	2±1	12
12AY7	R	65K	22M	88K	3.9	3.9	65K	268K	88K	3.6
V8	V	175	-94	-1	18	24	15	-92	0±1	-3
6GH8A	R	21K	1.2M	1K	4	3.4	64K	8K**	6K	240K
V9	V	--	6AC#	435ac	--	435ac	--	6AC#	325	--
6AX5GT	R	--	--	8.5K	--	8.5K	--	--	27K	--
V10	V	170	6AC#	175	--	315	--	6AC#	315	--
6AU5GT	R	490K	--	20K	--	28K	--	--	28K	--
V11	V	--	-85	--	--	0	--	--	--	--
0G3/85A2	R	--	17K	--	--	0	--	--	--	--
V12	V	170	2±1	0	0	12	125	-87	-85	--
12AX7A	R	490K	775K	0	0	7.5	210K	273K	17K	--
V13	V	175	-5	0	0	12	175	-5	0	--
12AU7A	R	21K	775K	0	0	7.5	21K	775K	0	--
V14	V	120	0	1±1	12	24	175	0±1	1±1	--
12AX7A	R	210K	0	108K	7.5	3.3	21K	775K	108K	--
V15	V	120	0	1±1	24	12	120	0±1	1±1	--
12AX7A	R	210K	0	500K	3.3	7.3	185K	250K	500K	--

(B)

* With Zener diode Z101 shorted
** With Zener diode Z301 shorted
\# Voltage measured between pins 2 and 7

Figure 17. Schematic Diagram and Voltage/Resistance Chart

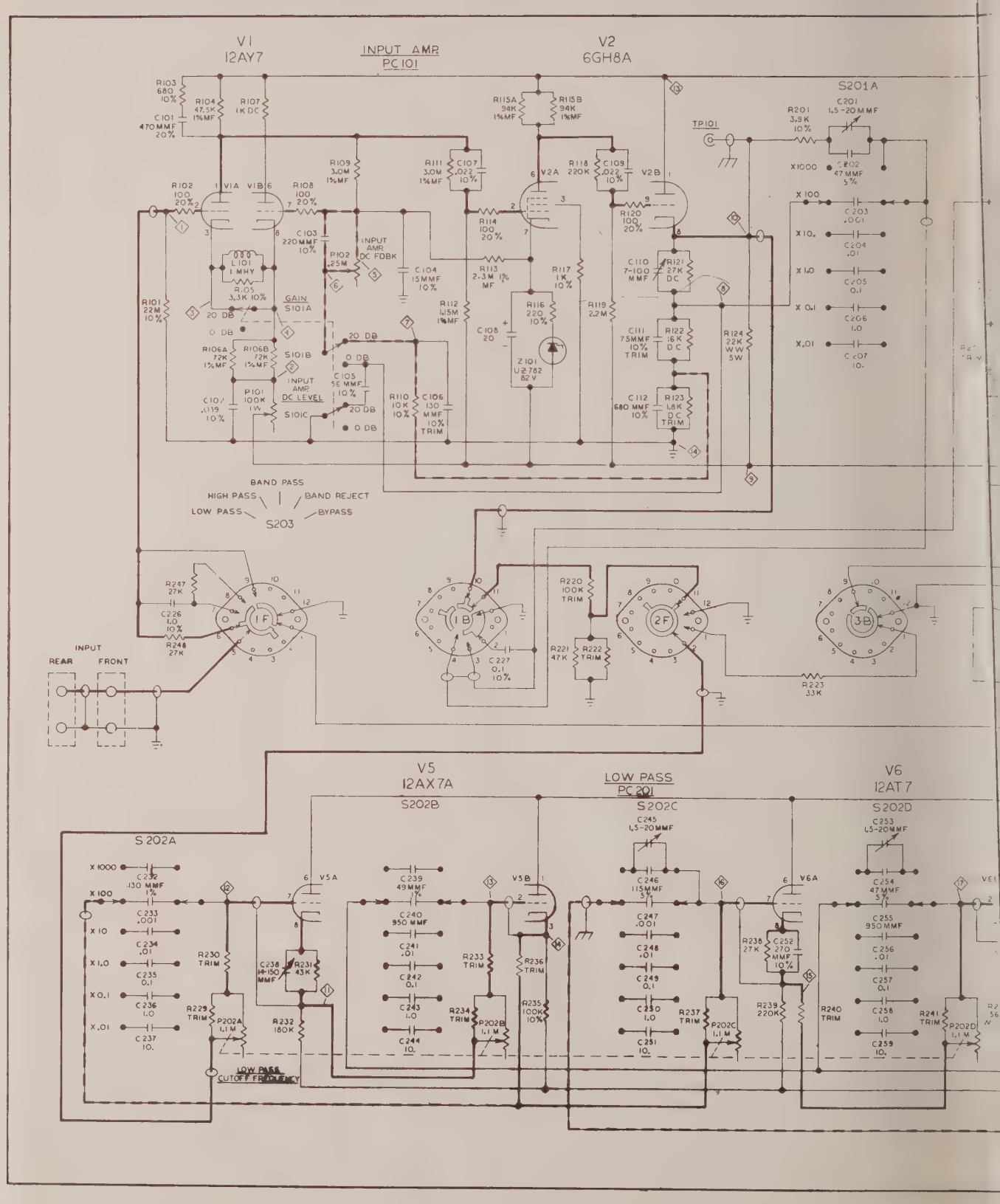
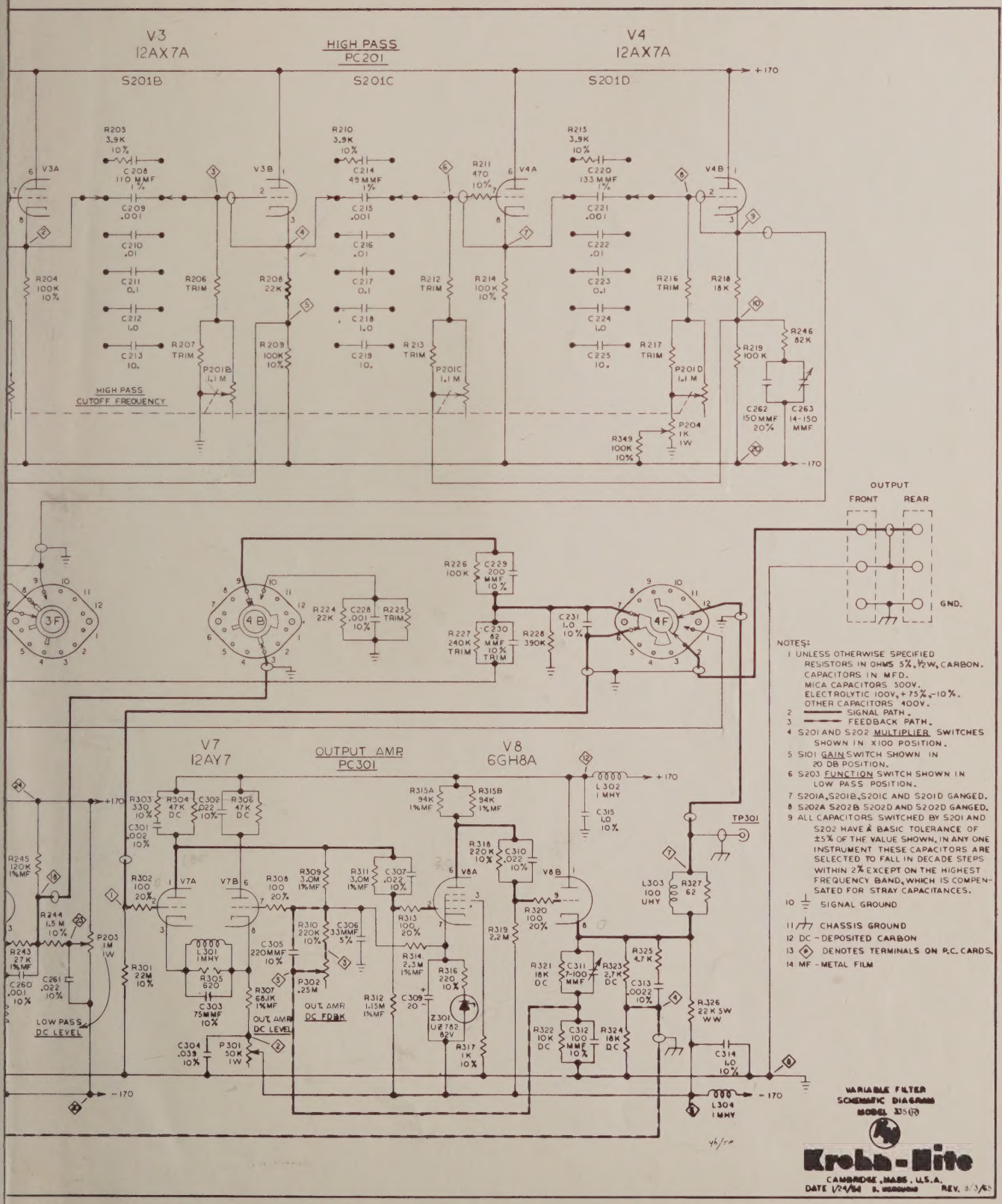


Figure 17. Schematic Diagram



and Voltage/Resistance Chart

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